BIOLOGY

A TEXTBOOK FOR HIGHER SECONDARY SCHOOLS

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BIOLOGY

A TEXTBOOK FOR HIGHER SECONDARY SCHOOLS

(*Classes XI—XII*)

PART II

(*Volume II*)

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Foreword

THE present volume is the continuation of the Class XI biology textbook. It deals with the concepts pertaining to the important areas of biology such as Cell Biology, Genetics, Developmental Biology and Applications of Biology to Human Welfare All these concepts are developed on the basis of the previous knowledge of the students. The authors who are experts in these areas of biology have attempted to enrich the students with contemporary knowledge so that they may develop interest in pursuing higher level of education.

I wish to express my thanks to the authors and reviewers for undertaking the work and completing it in so short a time.

The book was prepared in a great hurry to meet the deadline of publication, and there may be some errors in the book Suggestions pointing out errors and comments towards the improvement of the book are cordially invited.

S. K. MITRA
Director
National Council of
Educational Research and Training

New Delhi
23 *September* 1978

Preface

In the contemporary period, biology has made great advances which have influenced all major branches of human knowledge The solutions of major problems, like those of food, health and shelter, are expected from the pursuit of biological sciences. The student of biology can acquire a perspective of all facets of the subject by a proper understanding of the structural and functional organization of plants, animals and man While learning the historical developments and modern trends, the student will have to be aware of the application and significance of his biological background in his day-to-day living It will help him to enter various academic and professional pursuits or to enter life with greater satisfaction as regards his knowledge of living surroundings, processes and phenomena.

The present textbook for Class XII has been developed to meet the above needs I would like to thank all members of the editorial board, the authors and the reviewers for completing the work within a short period. Since the writing, reviewing and editing had to be completed in a great hurry to meet the deadline of publication, there are bound to be errors appearing in the book. These will be rectified in a subsequent edition.

We welcome comments, criticism and suggestions from the users of the book

M. R. N. Prasad
Chairman
Biology Editorial Board
for Classes XI - XII

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CHAPTER 1

Introduction

IN ITS life time, an organism passes through certain recognisable stages like birth, growth, reproduction and death. The parents die and disappear but the progenies continue to repeat the life cycle generation after generation.

A study of plant development may be conveniently started with the zygote which is the fusion-product of two haploid (having only one set of chromosomes) sex cells—the gametes. The act of gametic fusion is called fertilization, an important phenomenon in sexual reproduction. Since two haploid gametes are involved in fertilization, the resulting zygote will be diploid. Imagine the situation if in each life cycle the chromosome number were to become double! The progeny would have such an enormous number of chromosomes in five to six generations that there would be no space in their cells for any other organelle! Fortunately, this does not happen, and every plant species maintains a fixed number of chromosomes. This is achieved through an ingenious event, called meiosis, during sexual reproduction. It is a special type of cell division in which a cell gives rise to four daughter cells, each containing half the number of chromosomes present in the parent cells This reduction in the chromosome number precedes gamete formation, with very few exceptions.

The stage of life cycle at which meiosis occurs varies with different groups of plants. In algae such as *Chlamydomonas*, *Spirogyra* and in fungi like *Rhizopus* it occurs before the zygote germinates to give rise to a new individual. In such examples the main plant body is haploid, and is called gametophyte because it bears gametes. The diploid spore-bearing phase (sporophyte) is very brief and is represented by the zygote. In liverworts and mosses (Bryophytes) also the main plant body is a gametophyte but a distinct sporophytic phase occurs. The zygote, through simple mitotic divisions, first develops into a multicellular, well-differentiated and organised sporophyte. The latter is borne on the gametophyte. Some of the specialised cells of the sporophyte, called spore-mother cells, undergo meiosis to give rise to haploid spores. The spores are set free by the dehiscence of the sporophyte and they germinate to form independent gametophytes. Thus, in the life cycle of a Bryophyte, two distinct generations—the gametophytic and the sporophytic—occur which normally alternate with each

other in a definite sequence. In Pteridophytes (ferns, *Selaginella*, etc.) also the phenomenon of alternation of generations is very distinct. In these plants the initial development of the sporophyte occurs on the gametophyte. However, it eventually becomes independent and shows an elaborate differentiation into true roots, shoots, leaves and vascular tissues. In Pteridophytes and seed-bearing plants (Gymnosperms and Angiosperms), the sporophytic phase dominates the life cycle. There is, however, a major difference among these groups of plants. In Pteridophytes, the gametophytic phase occurs independently of the sporophyte. In the seed plants, the gametophyte is highly reduced and produces the gametes while still enclosed within the sporophytic tissues

In lower plants, such as *Chlamydomonas* and *Spirogyra*, the contents of any body cell may be directly transformed into one or more gametes. All the gametes look identical and it is difficult to tell in a pair of fusing gametes which is male and which is female (isogamy—fusion of similar gametes). Generally, however, identical gametes from the same cells do not fuse, and fertilization occurs only if they belong to different cells. In plant groups which are slightly more evolved, a clear difference is observed in the size and motility of the mating gametes (anisogamy—fusion of dissimilar gametes). In certain plants, no special sex organs may occur but in others the sex organs may be highly specialized. The male sex organs that develop on the gametophytes in Bryophytes and Pteridophytes are referred to as antheridia and the female sex organs are termed archegonia. These differ in structure, position and in the number of gametes they form.

Where distinct sex organs occur, the male gametes are called sperms (strictly speaking, the term sperm is restricted to the motile gametes as in Bryophytes, Pteridophytes and some Gymnosperms) and the female gametes are called eggs. The latter are non-motile and are produced in fewer number than the male gametes To bring about fertilization, the male gametes or entire male gametophytes (pollen grains) are liberated from the plant and they find their way to the female sex organs In Bryophytes and Pteridophytes, the sperms swim through the neck of archegonium and reach the egg located at its base. However, in seed plants, the gametes might have to travel several miles before reaching the egg, and are enclosed within the pollen grains. On reaching the female sex organs, the pollen grains germinate and transport the male gametes to the egg.

In Bryophytes, Pteridophytes, and Gymnosperms, nutrition for the development of the new sporophyte is provided by the gametophytic tissue but in flowering plants, a special tissue—the endosperm, formed as a result of fertilization—fulfils this role. In Gymnosperms and Angiosperms, the sporophyte does not show continued development into an adult form. The growth temporarily stops after a certain period, when the embryonic plant has been formed. The embryo remains enclosed in the surrounding tissues of the sporophyte which together constitute the seed. Seeds carry the embryonic sporophyte to long distances and help them establish in new localities.

In this section, we will first study the developmental stages in representatives from each plant group and then examine in detail the pattern of growth and development in flowering plants.

EXERCISES

1. What do you understand by "alternation of generations"? Illustrate your answer with a suitable example.
2. Explain the significance of sexual reproduction in the life cycle of a plant.

Bacteria (Escherichia coli)

BACTERIA are single-celled organisms (Fig. 2.1). They occur almost everywhere—inside the human body, in soil, in water as well as in air. While some bacteria such as the nitrogen fixing bacteria present in the root nodules of leguminous plants, are extremely useful, there are others which cause deadly diseases. Bacteria are among the simplest of plants. They differ from

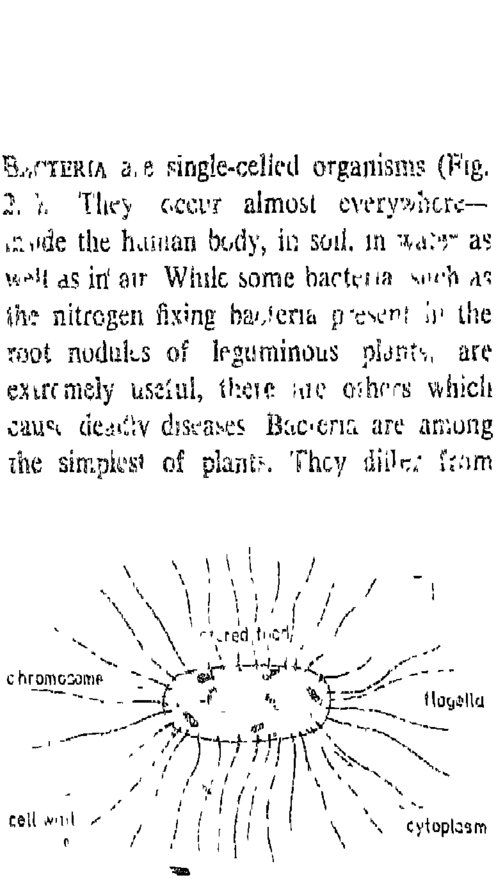


Fig. 2.1 Generalized diagram of a bacterial cell. (*From Biological Science : An Inquiry into Life, Harcourt Brace & World Inc., New York, 1963*).

animals in having a rigid cell wall which gives them the characteristic shape, and in being able to synthesize vitamins. Being very minute (0.5–3 μm), bacteria are not visible to the naked eye. Even under the light microscope only the gross structure of the cell can be seen. Bacteria may be rod-shaped, spherical or spiral. Details of the bacterial cell have come to light with the development of electron microscopy.

On the basis of their wall structure and stainability, bacteria are classified into two large categories: Gram +ve and Gram –ve. With crystal violet dye, all bacteria stain blue. When these are subsequently treated with iodine solution and decolourised with alcohol, some bacteria retain the blue colour while others lose it. The former are designated Gram +ve and the latter Gram –ve. *E. coli* is a Gram –ve bacterium.

Escherichia coli is a rod-shaped bacterium found in the human intestine. The cells are 1–3 μm long. The cell wall in this and other Gram –ve bacteria consists of two layers: an inner layer called murein (polysaccharide + small peptide chains) and an outer layer made of lipopolysaccharides (fat + carbohydrate) in which are present lipoprotein tubules. In Gram +ve bacteria, however, the wall is only monolayered, equal to murein described above. Gram –ve bacteria are usually more resistant to antibiotics. The

cytoplasm in a bacterial cell does not show streaming movement unlike that present in the cells of the higher plants The cytoplasm lacks mitochondria, plastids and endoplasmic reticulum but contains reserve food material in the form of glycogen granules (Fig. 2.1)

The bacterial cell lacks the conventional nucleus but has a single chromosome, made up of two chains of DNA wound round each other. The chromosome is ring-shaped and is embedded in the cytoplasm, generally in the centre of the cell (Fig. 2 1) The cytoplasm is lighter in the area of DNA. In *E coli*, flagella (120-150 A° in diameter) are present all over the surface of the cell. In addition, the 'male' cells have minute hairlike appendages (30-50 A° in diameter) extending from the cell wall These are called sex pili because they help the male cell to become attached to the female cell during sexual reproduction.

Bacteria reproduce chiefly by the asexual method of binary fission (Fig 2.2) in

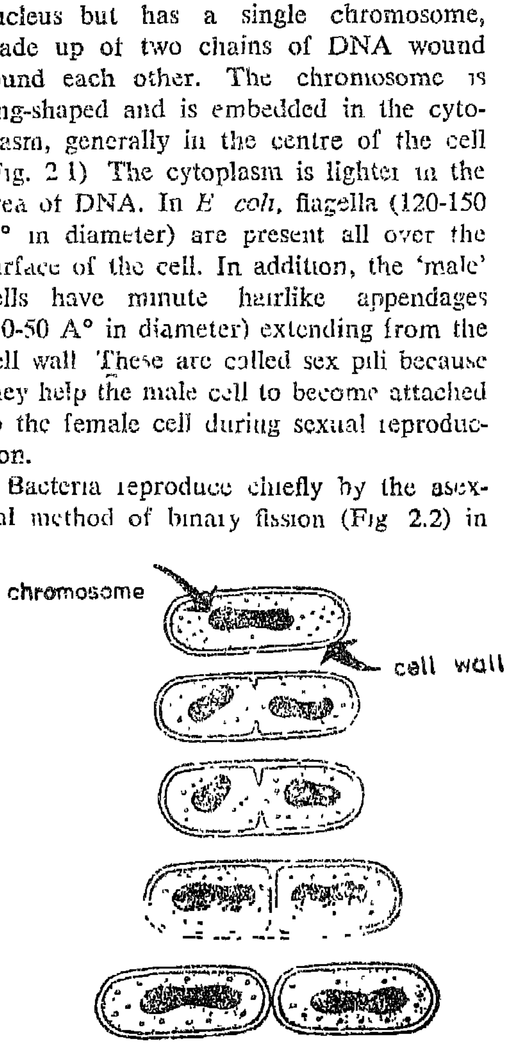


Fig. 2 2 Binary fission in a bacterium. The division of the cell is preceded by the division of the chromosome (*From Biological Science : An Inquiry into Life, Harcourt Brace & World Inc , New York,* 1963).

which the cell divides into two identical halves, and each half grows into a new individual During binary fission, the nuclear material divides first, followed by the splitting of the cytoplasm by the laying down of a transverse cell membrane. Subsequently, centripetal growth of the cell wall splits the cell into two. While in higher organisms cell division results in the growth and development of the organism, in bacteria it increases the number of individuals. After division, each individual grows until it attains a critical size and then again divides The rate of division varies greatly but under optimal conditions of nutrition, water and temperature, it may occur once every 20 minutes If this rate of multiplication was maintained for 20 hours, each bacterium would produce a bacterial mass equivalent to 2,000 tonnes. Fortunately, however, this never happens because the nutrients become depleted, and also because large quantities of harmful materials secreted by the bacterial cell accumulate in the medium.

The first indication of the occurrence of sexuality in bacteria was given by Lederberg and Tatum (1946). They grew different strains of *E. coli* together and obtained some new types showing combination of parental characteristics, suggesting the transfer of genetic material from one type to the other Subsequently, electron-microscopic pictures have confirmed that bacteria show sexual reproduction *E. coli* is a dimorphic bacterium in the sense that the male cells are equipped with the sex pili which are absent in the female. During sexual reproduction, the male and the female bacteria come together and a cytoplasmic bridge is formed between them Through this tube the genetic material of the chromosome from the male cell passes into the female cell. This method of reproduction is called *conjugation* A special

feature of bacterial conjugation is that it can be automatically terminated at any stage. Generally, only a part of the chromosome from the male is transferred to the female cell. The introduced DNA either replaces a part of the original DNA in the female cell or merely adds to it, and this establishes genetic variations in the offspring. Unlike the situation in higher organisms, in bacteria a true diploid condition is not attained. Thus, bacteria do not exhibit alternation of gametophytic and sporophytic generations.

E. coli has been widely used as research material to understand basic cell functions, such as gene action and protein synthesis. This is because the bacterial cell is haploid, has short life-cycle, and gene recombination can occur through transduction and transformation, besides conjugation.

The salient features of *E. coli* as representing the group Bacteria are:

1. It is a prokaryote, lacking a true nucleus.
2. In sexual reproduction, only a portion of the chromosome is transferred to the female cell.

EXERCISES

1. With the help of a suitable diagram, describe the structure of a bacterial cell.
2. How does the bacterial cell differ from the green cell of a flowering plant ?
3. Describe the asexual cycle in a prokaryote that you have studied.
4. Why are bacteria considered as plants and not as animals ?
5. Explain the following: (a) conjugation in *Escherichia coli*, (b) Gram +ve and Gram –ve bacteria, and (c) sex pili.

CHAPTER 3

Chlamydomonas

CHLAMYDOMONAS is a unicellular, free-floating, green alga. It is widely distributed in standing fresh water and damp soil. In the presence of a large number of these cells, a pond may appear bright-green.

The body cell (Fig. 3.1A) is ellipsoidal, round or pear-shaped. It is bound by a definite, cellulosic wall. In some species, the cell wall is surrounded by a gelatinous sheath The cell has two flagella of equal length, arising at the pointed, colourless end. Motility of the cells is achieved by these flagella. A pair of contractile vacuoles is present near the base of the flagella. These are regarded as excretory in function. Laterally, near the pointed end of the cell is present a well-developed, red eye-spot which is sensitive to light. It controls the movement of the cell towards light when it is diffuse and away from it when it is too bright. The cell contains a single cup-shaped chloroplast, which is often so large that it occupies most of the protoplast at the broader end of the cell. A single round proteinaceous body, called pyrenoid, is embedded in the chloroplast. The nucleus is centrally placed in the cytoplasm

Asexual reproduction occurs by means of zoospores (Fig. 3.1 A-D). The haploid body cell loses motility by shedding off the flagella, and its protoplast divides longitudinally into 2, 4, 8 or 16 (typically 4) daughter protoplasts (Fig. 3.1 B, C). Each protoplast develops a wall around it and a pair of flagella. These daughter cells, also called zoospores, are liberated by the rupturing of the parent cell wall (Fig. 3.1 D). Each zoospore grows directly into a mature and motile individual. In plants growing in damp soil, rather than in water, the daughter cells do not develop flagella and remain enclosed within a gelatinous matrix formed by the dissolution of the parent cell wall. Within each matrix a colony of hundreds and thousands of cells may be formed. However, as soon as the colony is flooded with water, the individual cells develop flagella and escape from the matrix.

Chlamydomonas shows the simplest kind of sexual reproduction in plants (Fig. 3.1 E-L). It is usually isogamous (in which gametes are morphologically similar) but some species do exhibit anisogamy (gametes being morphologically dissimilar). The protoplast of each vegetative cell divides as in asexual reproduction and gives rise to 2, 4, 8 or 16 small cells (Fig. 3.1E). Each cell is furnished with a pair of

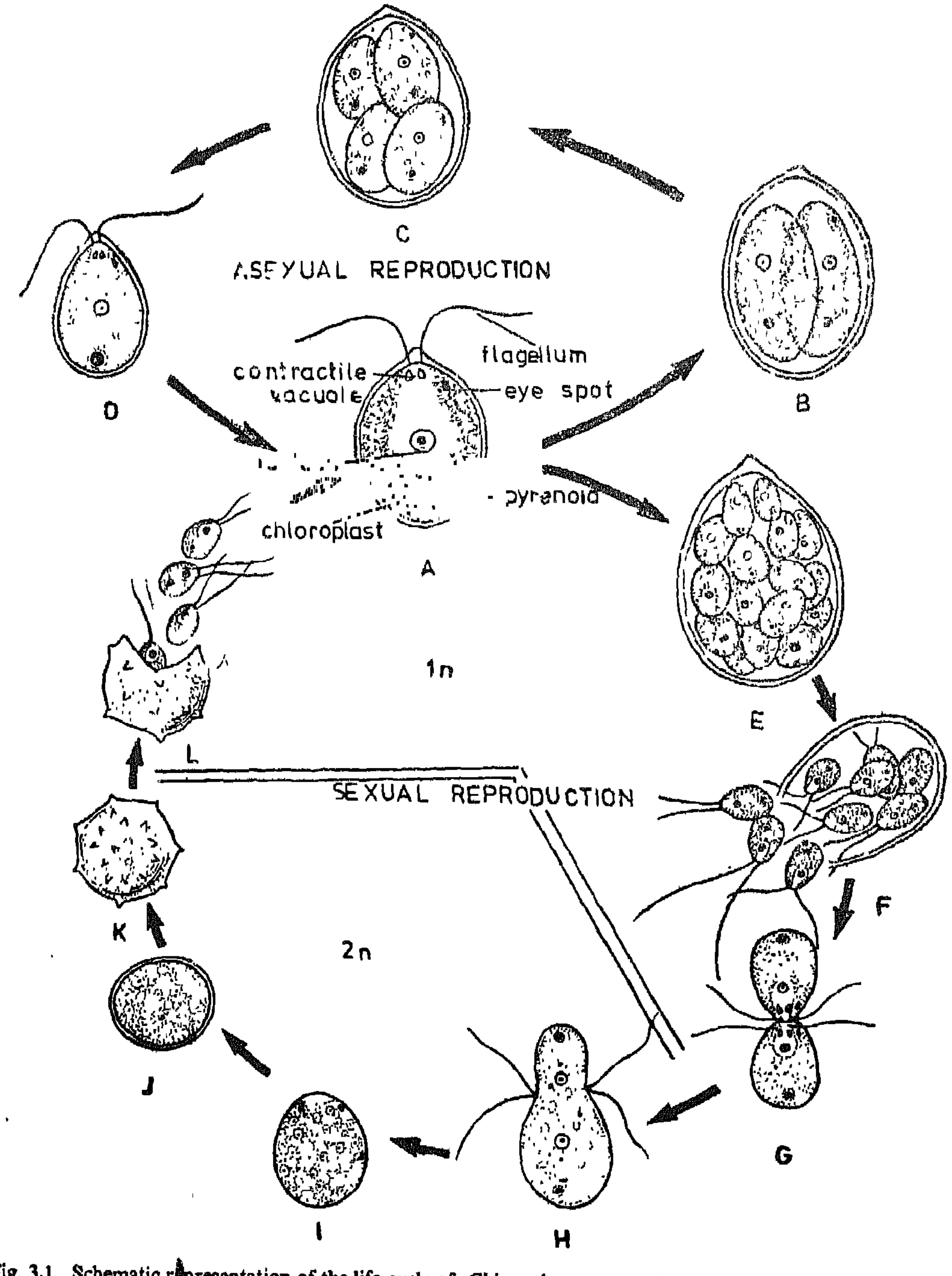


Fig. 3.1 Schematic representation of the life cycle of *Chlamydomonas*. *A-D*—Asexual reproduction; *E-L*—Sexual reproduction; *A*—An adult individual; *B-C*—Division of the protoplasm to form 2 and 4 zoospores, respectively; *D*—A young zoospore which would gradually grow into the adult; *E*— The cell has lost the flagella and has formed numerous gametes; *F*—Wall of the parent cell has burst to release the gametes; *G-J*—Stages in the fusion of two gametes; *K*— Zygote with thick wall; *L*—The zygote has ruptured and released haploid zoospores.

flagella (Fig. 3.1F) and functions like a gamete. These gametes are liberated by the breakdown of the parent cell wall (Fig. 3.1F). Alternatively, the flagellate vegetative cell may directly function as a gamete The gametes are chemically of two different types designated as plus (+) and minus (−); the (+) gamete can mate only with the (−) gamete and not with a gamete of its own type. Similarly, a (−) gamete cannot mate with another (−) gamete The gametes fuse by their pointed end (Fig 3 1 G. H) and shed their flagella (Fig 3 1 I). The contents of the two gametes fuse, establishing a diploid zygote (Fig. 3.1J) In some species, the zygote may retain the four flagella and remain motile for as long as two weeks. After losing the flagella, the zygote develops a thick wall (Fig. 3.1K), and in this state it can withstand adverse climatic conditions. Under favourable conditions, the zygote undergoes a meiotic division forming four haploid zoospores which are set free by a break in the zygote wall (Fig. 3.1L). Soon after liberation, each zoospore develops a pair of flagella and matures directly into a vegetative cell Sometimes, the products of meiosis undergo further mitotic divisions resulting in the production of 8-32 zoospores within the parent wall.

In this organism, although the haploid gametophytic phase of life is dominant, a distinct diploid, sporophytic phase is established which is represented by the zygote

EXERCISES

1. Explain what is meant by isogamy with reference to *Chlamydomonas*
2. Draw a labelled sketch of a vegetative cell of *Chlamydomonas*
3. Describe the mode of sexual reproduction in *Chlamydomonas.*
4. Describe the asexual reproduction in a unicellular alga.

CHAPTER 4

Spirogyra

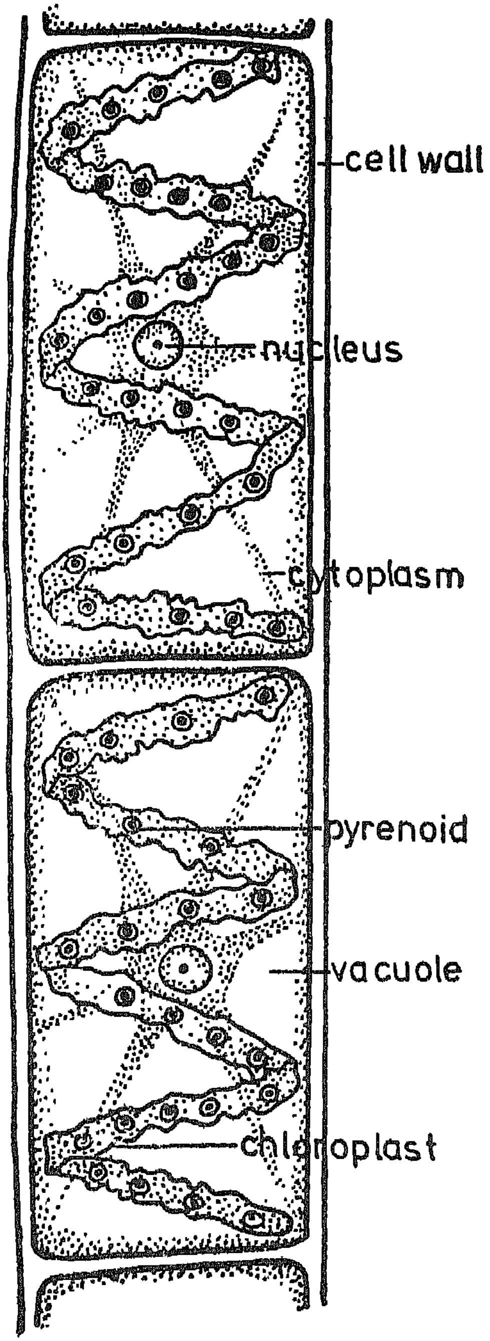
SPIROGYRA is a multicellular, filamentous, unbranched, green alga. It occurs as slimy, dark-green masses in fresh-water ponds and in slow streams. All the cells of a vegetative filament appear identical (Fig. 4.1). The cell wall comprises an outer layer of pectic material and an inner cellulosic layer. The filaments are enclosed by a mucilaginous sheath.

A cell has one or more prominent chloroplasts (Fig. 4.1). The alga has derived its name from the characteristic spiral arrangement of its chloroplasts which run anti-clockwise within the cell. Numerous large pyrenoids are embedded in the chloroplasts. The central region of each cell is occupied by a large vacuole, and the cytoplasm is restricted to the periphery. The nucleus is usually suspended in the central vacuole by cytoplasmic strands.

This alga does not reproduce asexually. However, vegetative multiplication by fragmentation of the filaments is very common. In this process, a filament breaks into two or more small portions, each of which is capable of growing into a new filament by mitotic divisions.

Spirogyra is a haploid, haplobiontic organism, meaning thereby that it has only one type of free living thallus which is haploid. Sexual reproduction in this alga takes place by conjugation (Fig. 4.2). In this process two compatible filaments become intimately united along their lengths (Fig. 4.2A). This is followed by the development of small protuberances from the cells of both the filaments (Fig. 4.2B). The protuberances arise on the side facing the other filament and these are so arranged that opposite cells have them at the same level. The protuberances gradually grow and come to touch each other. In this process, the two filaments are slightly pushed apart. Subsequently, the walls between them dissolve and a tube connecting opposite cells is formed (Fig. 4.2C). While a conjugation tube is being formed, the protoplasts in the cells round off, forming gametes. The contents of one cell migrate, through the conjugation tube, into the other connected cell (Fig. 4.2C). Here it fuses with the protoplast of the recipient cell. The nuclear fusion occurs soon after cytoplasmic fusion and a diploid zygospore is formed (Fig. 4.2D).

Depending on the species, all the gametes from one filament may pass into the



ig. 4.1 A portion of the vegetative filament of *Spirogyra.*

cells of the other filament so that after migration one filament would appear empty. In such a case, the donor filament is designated as male and the recipient as female. Such species with sexually different types of filament are described as heterothallic. In homothallic species, such distinction of filaments does not occur. In these species, conjugation may occur between the adjacent cells of the same filament. When two filaments are involved, each one would have donor as well as recipient cells. Conjugation between the cells of two filaments (whether homothallic or heterothallic) is known as scalariform (ladderlike) and that between the two cells of the same filament is known as lateral conjugation

The zygospores of *Spirogyra* are globular or ellipsoidal (Fig. 4.2E), and remain dormant for some time. During this period, the diploid nucleus undergoes meiosis, and four haploid nuclei are formed (Fig 4 2F) Of these, three nuclei degenerate and only one survives (Fig 4.2G) At germination, the thick wall of the zygospore ruptures and a small tube or germling, carrying the protoplast of the zygospore, emerges (Fig. 4 2H). By repeated mitotic divisions and growth of the daughter cells, the germling gives rise to a new fully-developed filament.

The salient features of the life cycles of *Chlamydomonas* and *Spirogyra* as representing the group Algae are :

1 Simplest green plants adapted for living in water.

2. Meiosis occurs before the germination of the zygote, and the main plant body is a haploid gametophyte.

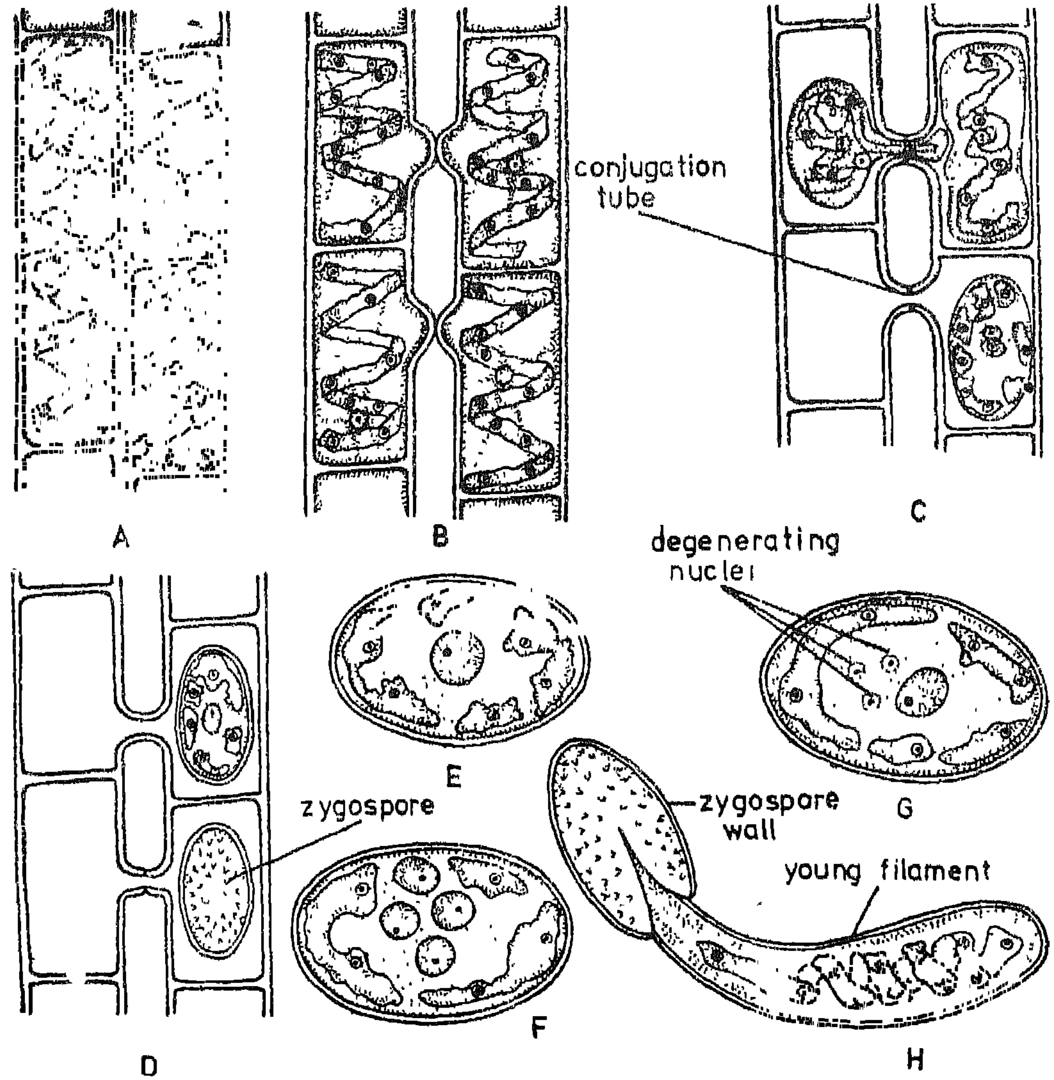


Fig. 4.2 Sexual reproduction (scalariform conjugation) in *Spirogyra* (only portions have been enlarged to show details). *A*—Two filaments have come to lie side by side, *B*—Papillate protuberances have developed from opposite cells; *C*—In the upper set of cells the contents of the donor cell (left) are seen migrating through the conjugation tube to the recipient cell (right), whereas in the lower pair migration of the cell contents is complete; *D*—Zygospore within the recipient cell; *E*—Zoospore liberated from the filament; *F*—Meiotic division in the zygospore has given rise to four haploid nuclei; *G*—Three of the four nuclei have degenerated; *H*—A zygospore has germinated and formed a young filament.

EXERCISES

1. Draw a labelled sketch of a vegetative cell of *Spirogyra* and compare it with that of *Chlamydomonas*
2. Compare the mode of sexual reproduction in *Spirogyra* and *Chlamydomonas*.
3. If three filaments of *Spirogyra* are conjugating at the same time, where will you find zygospores ?

CHAPTER 5

Rhizopus

FUNGI are characterized by the complete absence of chlorophyll and, consequently, their inability to synthesise food. Such organisms are known as heterotrophic. While some fungi derive their food from other living organisms (parasitic), others live on dead organic matter (saprophytic) *Rhizopus* is a common and well-studied saprophytic fungus.

If a piece of moist bread is kept under a bell-jar, it would show a white, cottony structure appearing on its surface in a few days which represents the vegetative phase of *Rhizopus*. It would subsequently become black due to the development of dark-coloured spores of the fungus. For this reason, the fungus is commonly called the black-mould. The other popular name of the fungus is bread-mould. It would grow on a variety of substrates, such as tuberous roots of sweet potato and several fruits.

A microscopic examination of a small patch of the fungus would show that it comprises a mesh of numerous intertwined threadlike structures called hyphae. The individual thread is called a hypha. Each hypha is multinucleate and aseptate (coenocytic condition).

The mycelium of *Rhizopus* consists of two types of vegetative hyphae (Fig. 5.1A). Some hyphae grow horizontally on the surface of the substrate forming a network. These are called stolons. At intervals, the stolons bear bunches of rootlike appendages which penetrate the substrate; these are the rhizoids. Besides providing anchorage, the rhizoids secrete certain enzymes which convert the solid food materials in the substrate into a soluble form. These are then absorbed by the fungus through the rhizoids. Thus, in this fungus the digestion of food is extracellular.

Under favourable conditions one or more erect hyphae develop from the stolon directly above the rhizoids (Fig 5.1 A). These are known as sporangiophores. The tip of the sporangiophores become swollen, and a large amount of cytoplasm carrying many nuclei flows into it and becomes concentrated towards the periphery. The peripheral region is now demarcated from the central region by the laying down of a semi-circular wall (Fig. 5.1 B, C). The highly vacuolated and dome-shaped central region is called columella and the peripheral region constitutes the sporangium. Thousands of multinucleate spores are formed in each sporangium (Fig. 5.1

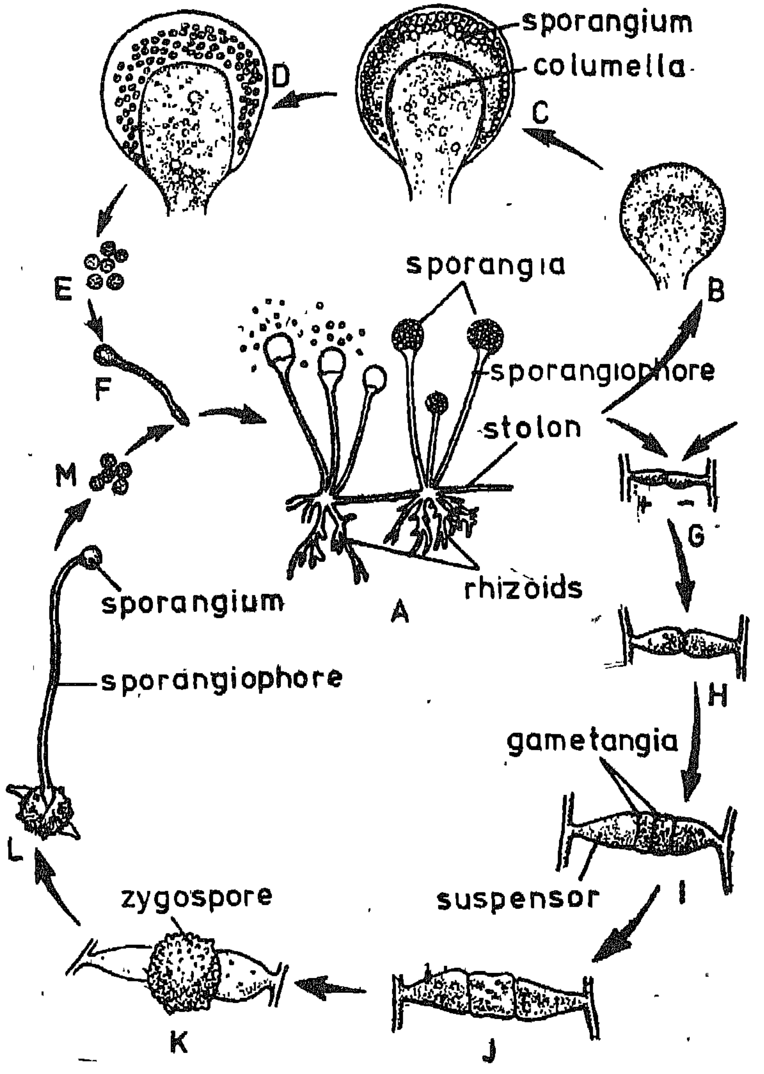


Fig. 5.1 Schematic representation of the life cycle of *Rhizopus*. *A*—A portion of the stolon bearing rhizoids and two clusters of sporangiophores; sporangia in one of the clusters (left) have dehisced to liberate the spores; *B-F*—Asexual reproduction; *B-D*—Stages in the development of a sporangium; *E*—Spores; *F*—A germinated spore; *G-M*—Sexual reproduction; *G-H*—Conjugation of the progametangia of a plus and a minus strain; *I*—Formation of cross-walls separating the gametangia from the suspensors; *J*—Dissolution of the contact-wall of the gametangia and mixing of their contents; *K*—The body derived from the fusion of the two gametangia has developed into a zygospore by secreting a thick and rough wall around it; *L*—A germinated zygospore; *M*—Spores.

C, D). At maturity, the spores turn black. The spores are liberated by the bursting of the sporangial wall (Fig. 5.1 A, E) and are carried to long distances by air currents. On a suitable substrate, and under favourable conditions of temperature and

humidity, a spore germinates to produce a new hypha (Fig 5.1 E, F).

Rhizopus is usually a [illegible] nism, which means that [illegible] types of physiological strains Since these strains are identical in appearance, they are designated as (+) and (−) The fungus can reproduce sexually only if the (+) and (−) strains are growing side by side because mating can occur only between the hyphae of opposite strains (Fig 5.1G)

The process of sexual reproduction in this fungus is very similar to the conjugation in *Spirogyra* When two compatible hyphae come in contact, they give out short branches (progametangia) towards the opposite partner (Fig 5.1 G, H). Some cytoplasm carrying many nuclei migrates into the swollen tips of the progametangia Soon after the two progametangia come in contact with each other, a septa is formed near their tips separating the terminal gametangium from the basal suspensor (Fig 5.1 I) The walls of the two gametangia dissolve at the point of contact and mixing of their cytoplasm occurs (Fig 5.1 J). The nuclei fuse in pairs, each with one (+) and one (−) nucleus Thus, diploid nuclei are formed The common cell resulting from the fusion of two gametangia enlarges considerably and develops a dark, thick and rough wall (Fig 5.1K) This structure [illegible] zygospore, can survive adverse climatic conditions When favourable conditions of temperature and humidity are available the zygospore germinates, its thick wall cracks and a sporangiophore emerges which later bears a terminal sporangium (also called germ sporangium) (Fig 5.1 L). During zygospore germination, the diploid nuclei undergo meiosis, again giving rise to haploid nuclei. At maturity, the sporangium bursts, liberating the haploid spores (Fig. 5.1M) These spores germinate and form new mycelia as described earlier.

Failure to observe zygospores in a culture of the fungus raised in a school laboratory is generally due to the absence of the two mating types If you inoculate portions of mycelia from cultures of (+) and (−) strains in a petri dish far away from each other, you will observe a line of zygospores in the centre resulting from conjugation (Fig. 5.2).

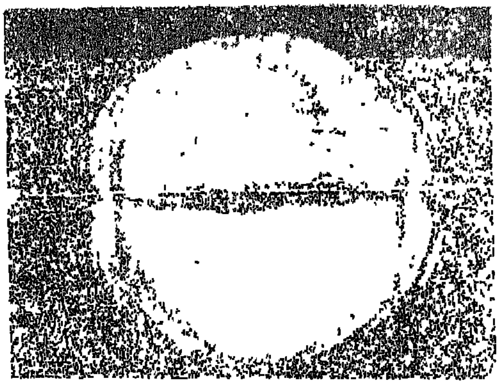


Fig 5.2 A plate showing mating of two strains of *Rhizopus*; a thick belt of zygospores (arrow-marked) is formed at the point of contact of the two strains (1 and 2) (*Courtesy Dr K. G. Mukerji, Department of Botany, University of Delhi*)

The salient features of the life-cycle of *Rhizopus* as representing the group Fungi are

1. The plant body is made up of thread-like hyphae, lacking true roots, shoots and leaves.
2. Being non-green, the fungi are either parasites or saprophytes
3. The sex organs are unicellular structures
4. As in algae, meiosis occurs before the germination of the zygote, and the main plant body is a haploid, gametophyte.

EXERCISES

1. Illustrate the life cycle of *Rhizopus* with the help of diagrams
2. Devise an experiment to demonstrate the presence of fungal spores in the atmosphere ∵ It has two different types of physiological strains.
3. *Rhizopus* is said to be heterotrophic and heterothallic What do you understand by these terms ? ∵ depends on other.
4. Explain the following terms (a) coenocytic mycelium, (b) extra-cellular digestion, (c) germ-sporangium (d) saprophyte and (e) columella
5. Why is it uncommon to find zygospores in a classroom culture of *Rhizopus* ?
6. Comment upon the statement "At least in one major feature fungi are more like animals than plants "

CHAPTER 6

Funaria

FUNARIA HYGROMETRICA (cord moss) is a common moss It belongs to the group Bryophyta, and grows luxuriently in shady and humid places. Mosses usually occur as green patches (Fig. 6.1) on damp walls, rocks and tree trunks, and on the forest floor. The dependence of mosses on humid environment can be related to two important features: (a) the sperms are flagellate and need water to swim to the egg cell in the archegonium, and (b) in the absence of the vascular tissue, the plants do not have an efficient transport system and, consequently, water is absorbed through the leaf surface

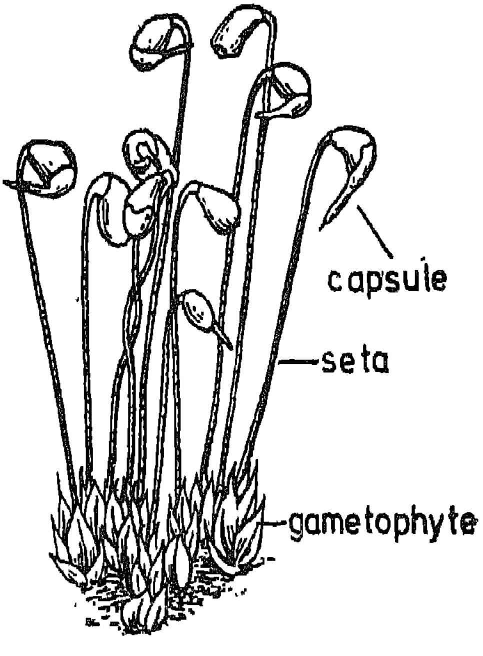


Fig 6.1 Habit sketch of *Funaria hygrometrica*, showing gametophytes bearing mature sporophytes. (*After H. C. Bold*, 1967, *Morphology of Plants, Harper & Row Publishers Incorporated, New York.*)

The life cycle of a moss plant consists of two multicellular phases—an independent, leafy gametophytic phase, and a partly dependent, sporophytic phase. The gametophytic phase dominates the life cycle. A gametophyte is a small plant measuring only a few centimetres. It has a tiny stem bearing small, green leaves arranged spirally in three rows (Fig. 6.2A). Unlike higher plants, a moss plant lacks the vascular tissue in the leaves and stem The plant is anchored to the substrate by means of slender, multi-cellular branched rhizoids arising from the base of the stem. The rhizoids are characterized by the presence of oblique walls.

Vegetative reproduction is widespread among mosses. Fragments of leaves, stem and primary protonema as well as secondary protonema and gemmae can give rise to a new plant.

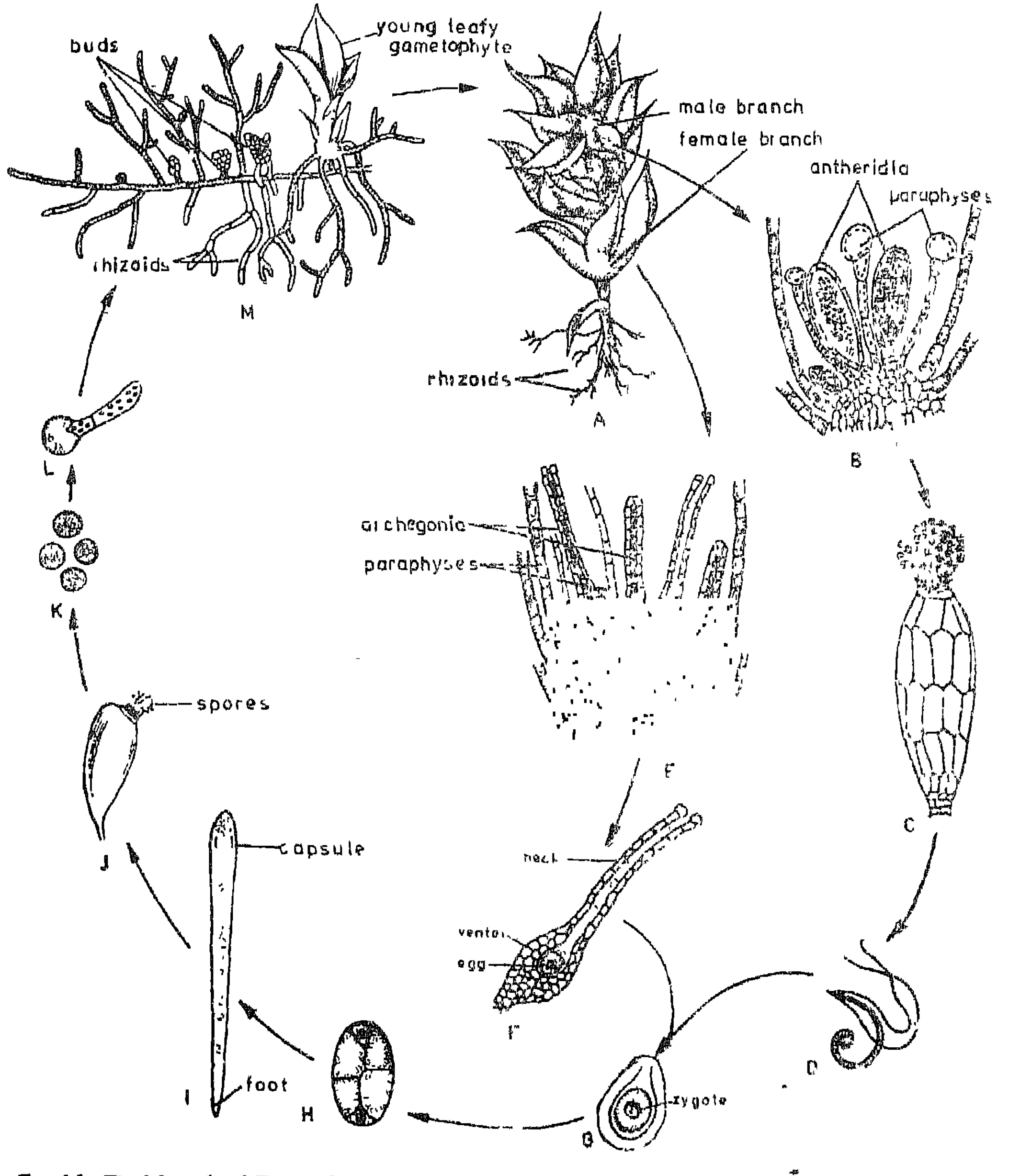


Fig 6.2 The life cycle of *Funaria hygrometrica*. *A*—A mature gametophyte bearing terminal male and lateral female branches; *B*—The apex of a male branch in longitudinal section, showing club-shaped antheridia intermixed with paraphysis; *C*—A mature antheridium has ruptured at the tip and liberated a mass of antherozoids, *D*— biflagellate sperm ; *E*—The apex of a female branch in longitudinal section showing a cluster of archegonia intermixed with paraphysis, *F*— An archegonium at the time of fertilization, *G*—Venter enclosing the zygote, *H* –An early stage in the development of sporophyte; *I*—A young sporophyte; *J*—A dehisced capsule liberating the spores, *K* – Spores; *L*—A germinated spore; *M*—Branched protonema bearing many buds and a leafy gametophyte. *After P.R. Bell and C. Woodcock, 1971, The Diversity of Green Plants, The English Language Book Society and Edward Arnold Publishers Ltd.*)

Sexual reproduction is brought about by highly specialized male (antheridia) and female (archegonia) sex organs. In mosses, the two sex organs may occur on the same plant (monoecious) or on different plants (dioecious). *Funaria hygrometrica* is a monoecious moss, the antheridia and archegonia are present on different branches of the same plant (Fig. 6.2A). They are borne in clusters (Fig. 6.2 B, E) on the tips of the branches. While the antheridia are present on the main branch, the archegonia develop on a lateral branch. The sex organs occur intermixed with uniseriate, sterile filaments, called paraphyses. In the male heads (Fig. 6.2B), the paraphyses terminate in a large globose cell, while in the female heads (Fig. 6.2E), these have pointed ends. These filaments prevent drying of the sex organs by holding water in between them.

An antheridium is a club-shaped structure borne on a short, multicellular stalk (Fig. 6.2B). Each antheridium has a sterile jacket enclosing a large number of cubical, spermatozoid mother cells (SMC). Each SMC eventually gives rise to a minute, biflagellate sperm (Fig. 6.2D). At the apex of the antheridia is a large, specialized cell which serves as a lid. Mature antheridia absorb water, and dehisce by the rupturing of the lid cell. The sperms ooze out of the terminal opening (Fig. 6.2C), swim about freely in the water and finally, reach the archegonia. The film of water entrapped between the leaves may provide the medium for this purpose.

The archegonia are also multicellular (Fig. 6.2E). Each archegonium is a flask-shaped body raised on a short stalk. It consists of two parts: (a) the swollen lower portion called venter, which encloses the egg cell and a ventral canal cell, and (b) the neck, which is extremely long and is composed of six vertical rows of neck cells; it encloses an almost equally long row of neck canal cells. When the egg is ready to be fertilized, the ventral canal cell and the neck canal cells disintegrate, making an open passage for the sperms to reach the egg (Fig. 6.2F).

Mature archegonia secrete a sugary solution at their tips that attract the sperms. Reaching the mouth of the archegonium, the sperms move down into the venter where the concentration of the sugar is much higher. One of the sperms fuses with the egg to form a diploid zygote (Fig. 6.2G). Once the egg has been fertilized, the additional sperms that had entered the archegonium degenerate.

After fertilization, the male branch withers off whereas the female branch continues to grow. The zygote develops a wall around it and starts dividing while still inside the archegonium. Several divisions ensue (Fig. 6.2H) and a multicellular sporophyte is formed (Fig. 6.2 I, 6.1). The latter remains attached to the gametophyte (Fig. 6.1) and obtains a part of its food requirements from it. Normally, only one sporophyte is formed on a gametophyte.

A fully grown sporophyte has three parts (Fig. 6.1). The basal part, called foot, is embedded in the gametophyte and absorbs food from it. The middle portion, known as seta, terminates in the spore-bearing part the capsule. The seta is a slender elongated structure and raises the capsule above the tuft of leaves of the gametophyte (Fig. 6.1). As the seta elongates, the archegonial wall gets ruptured and the distal portion of the archegonium remains surrounding the terminal portion of the capsule, forming the calyptra. The capsule (Fig. 6.3) is composed of a central cylindrical columella surrounded by the sporogenous tissue (spore-sac). Outer to this lies an area of chlorenchymatous tissue with a large cylindrical air space. The latter is traversed by 2-4-celled filaments, the trabe-

culae The outermost layer (epidermis) has some stomata The sterile, basal region of

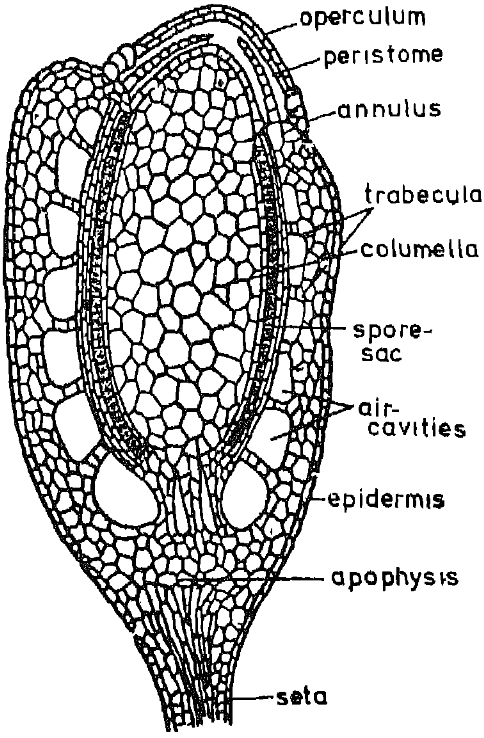


Fig 6 3 **Longitudinal section of a well-developed capsule to show its various tissues.**

the capsule is called apophysis. The capsule terminates into a lid called operculum which is connected to the capsular epidermis by a few specialized cells forming the annulus; in a mature capsule, the operculum breaks at this region. Just below the operculum is the peristome consisting of a circle of teeth all pointing inwards.

Each cell of the sporogenous tissue gives rise to four haploid spores through meiosis. When the capsule matures, the columella shrivels up, the operculum is thrown-off (breaks at the annulus), and the spores are liberated (Fig. 6 2J). The discharge of the spores occurs in small batches and this is regulated by the hygroscopic movement of the peristomial teeth.

Under conducive conditions, the spores germinate by giving out one or two germ tubes (Fig. 6 2 K, L) By repeated divisions, the germ tube forms a branched, flamentous protonema (Fig. 6 2M) The protonema derived from a single spore may grow to cover a circular area 40 cm in diameter. After a period of vegetative growth, some cells of the protonema give rise to minute buds, each of which may develop into a young, leafy gametophyte. Protonema originating from a single spore may develop several gametophytes This is the reason for the crowded growth habit of young moss plants. As the leafy gametophyte increases in size. slender rhizoids arise from the base of the stem and a new plant is established

The salient features of the life cycle of *Funaria* as representing the group Bryophyta are

1. Simplest green, land plants.
2. Lack vascular tissue.
3. Exhibit distinct alternation of gametophytic and sporophytic generations The former dominates the life cycle.
4. Sex organs are multicellular
5. Sperms are flagellate and water is necessary for fertilization
6. Sporophyte is borne on the gametophyte.

EXERCISES

1. Why do mosses generally occur in regions which are moist ?
2. Give a comparative account of the male and female reproductive organs of a moss.
3. Draw a labelled diagram of the longitudinal section of the moss sporophyte
4. Make a diagrammatic representation of the life cycle of *Funaria*.

CHAPTER 7

Selaginella

SELAGINELLA, commonly called the club moss, is cosmopolitan in distribution. However, most of the species are found in the tropics. It is a perennial plant occurring in moist and shady places. The stem is dichotomously branched prostrate or semi-erect. The leaves, referred to as microphylls, are arranged in four rows, two rows on the upper surface and one row along each margin of the stem The marginal microphylls are distinctly larger than those on the upper surface (Fig 7 1A) Each leaf bears a membranous outgrowth, called ligule, on its upper surface, near the base. This is a characteristic feature of *Selaginella*. From the under surface of the stem, at the points of dichotomy, arise special leafless, positively geotropic branches, called rhizophores, which grow downward into the substratum. Fibrous roots arise at the tips of the rhizophores.

Selaginella displays the familiar phenomenon of alternation of generations. The sporophytic generation dominates the life cycle. This is in contrast to *Funaria* in which the main plant body is a gametophyte.

The fertile regions of the plant, designated as strobili, occur terminally on the branches (Fig. 7.1A). Each strobilus bears two types of sporophylls· microsporophylls and megasporophylls. The distribution of the sporophylls in a strobilus may, however, vary with the species The sporophylls are leaflike structures bearing sporangia in their axils (Fig. 7.1B) A microsporangium borne on a microsporophyll is smaller than a megasporangium present on a megasporophyll. The former varies in colour from red to yellow to brown, and contains numerous small microspores (Fig. 7.1C). Megasporangia, on the other hand, are pale, with one to four megaspores (Fig. 7.1D) The number of megaspores produced varies from species to species. Both types of spores are tetrahedral and have ornamented walls (Fig. 7.1 E, F). The phenomenon of the occurrence of two types of spores on the same plant is known as heterospory. Thus, *Selaginella* is a heterosporous plant

A young microsporangium contains numerous microspore mother cells While some of them degenerate, others give rise to tetrads of haploid microspores through the process of meiosis. Each microspore develops into a male gametophyte within the confines of the spore wall. The development of the male gametophyte may

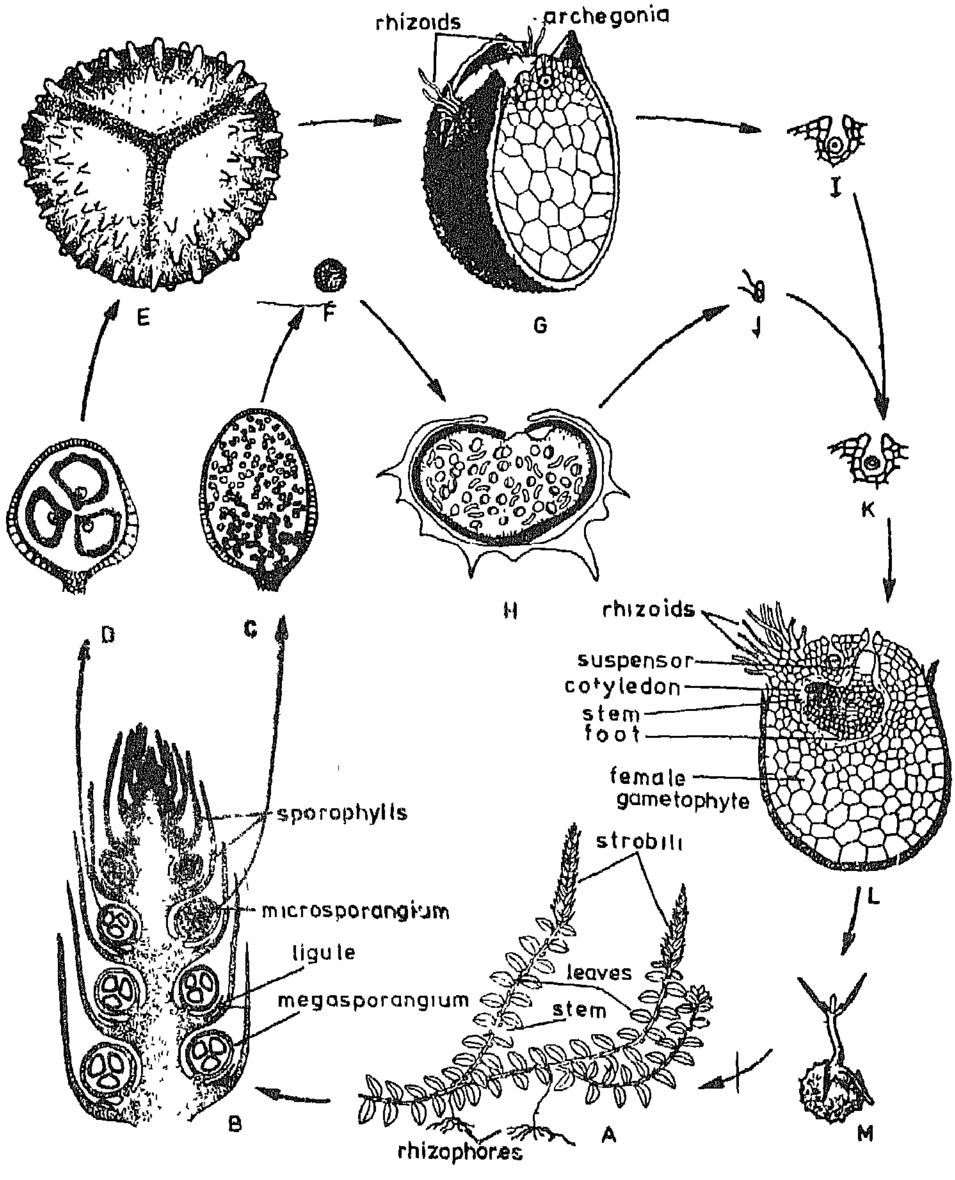


Fig. 7.1 The life cycle of *Selaginella*. *A*—Sporophyte bearing strobili, *B*—Longitudinal section of a strobilus showing the distribution of microsporophylls and megasporophylls on the central axis. Also note the position of the sporangia on the sporophylls; *C*—A microsporangium with numerous microspores, D—A megasporangium showing three of its four spores, *E*—Megaspore, *F*—Micro spore, *G*-female gametophyte bearing one mature and three developing archegonia, *H*—Male gametophyte enclosing male gametes, *I*—Archegonium at the time of fertilization, *J*—A biflagellate sperm; *K*—Archegonium after fertilization, zygote is formed; *L*-female gametophyte enclosing an embryo which shows the differentiation of shoot tip, cotyledons, foot and suspensor; *M*—Germinated embryo. (*A, B, E, F, H, I, J, K, M after A. Cronquist*, 1971, *Introductory Botany*, *Harper & Row, Publishers, New York*; *C, D after W. H. Muller*, 1969, *Botany — A Functional Approach, The Macmillan Company, New York*; *G adapted from H. Bruchmann*, 1911, *Flora, Vol* 104; *L after H Bruchmann*, 1909, *Flora, Vol* 99.)

start, while the microspores are still enclosed in the microsporangium. The male gametophyte consists of an ephemeral prothallial cell and a multicellular antheridium. The latter comprises a single-cell-thick jacket enclosing numerous sperms (Fig. 7.1H). Each sperm is furnished with two flagella at one end (Fig. 7.1J). The flagella assist the sperm in swimming in water to reach the archegonium for fertilization. The sperms are liberated when the spore wall cracks along the triradiate ridge

A megasporangium contains a large number of potential megaspore mother cells but usually only one undergoes meiosis, giving rise to four haploid megaspores (Fig 7 1D) The development of the female gametophyte also begins while the megaspore is still within the sporangium, and various stages of development are reached by the time of spore shedding Initially, the megaspore undergoes free nuclear divisions to form a multinucleate female gametophyte Subsequently, cell formation occurs in it A fully developed female gametophyte (Fig. 7 1G) has comparatively larger cells in its lower region The expansion of the female gametophyte within the megaspore causes the spore wall to burst at the apex, and to protrude out slightly. The exposed region of the gametophyte becomes green and develops a few rhizoids and many archegonia. Each archegonium is embedded in the gametophytic tissue and consists of a short neck and a slightly enlarged venter. The neck is composed of two tiers of four cells each, and encloses a single row of neck canal cells The venter comprises a ventral canal cell and an egg cell. At maturity, the canal cells degenerate, and the neck cells open out leaving an unobstructed passage for the sperms to reach the egg (Fig. 7.1I). Aided by their flagella, the sperms swim down the neck of the archegonium. On reaching the venter, one of them fuses with the egg to give rise to a zygote (Fig. 7.1K), the first cell of the sporophytic generation

Embryo development begins soon after fertilization. The first division of the zygote is always transverse The upper cell of the 2-celled proembryo forms a suspensor whereas the basal cell gives rise to the embryo proper The suspensor pushes the embryo deep into the gametophytic tissue, bringing it in contact with the lower nutritive tissue A mature embryo is a highly differentiated structure, at the junction of the stem and the rhizophore (Fig 7.1L) Although numerous archegonia develop in a female gametophyte, only one forms the sporophyte

The embryo grows through the surrounding gametophytic tissue and establishes a new sporophytic plant (Fig. 7.1M).

The salient features of the life cycle of *Selaginella* are .

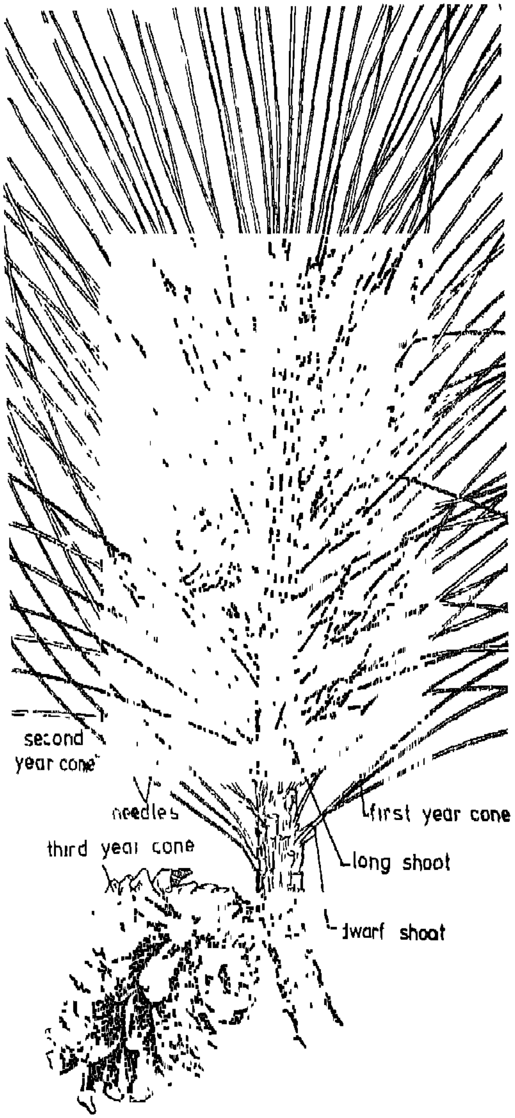
1 Plants bear rhizophores, stems, and leaves They possess a distinct vascular tissue which enables them to attain large size and to survive on land.
2 Exhibit distinct alternation of sporophytic and gametophytic generations.
3. Sporophytic generation, which dominates the life cycle, is independent of the gametophyte.
4. Like Bryophytes, these plants also depend on liquid water for fertilization.

EXERCISES

1. In what ways is water essential for the life cycle of a Pteridophyte ?
2. Enumerate the distinguishing features of Bryophytes and Pteridophytes
3. With diagrams trace the development of embryo in *Selaginella*
4. What do you understand by heterospory ?
5. Comment upon the validity of the following statements :
   (a) In Pteridophytes the gametophytic generation dominates the life cycle; (b) Sex organs are formed on the gametophyte as well as on the sporophyte, (c) Gametophytic and sporophytic generations are independent in Pteridophytes; (d) Microspores and megaspores give rise to male and female gametophytes, respectively.

CHAPTER 8

Pinus



PINES are tall, graceful, evergreen trees of immense economic importance They are the source of timber, resin, and paper pulp. The tree has a typical pyramidal shape because the lateral branches are almost horizontal and their length gradually decreases from below upwards. In India, pines are largely distributed in the Himalayas The tree represents a sporophyte.

The stem bears two types of branches: (a) Branches of unlimited growth or long shoots, and (b) Branches of limited growth or dwarf shoots (Fig. 8.1). The long shoots are present on the main trunk and show slow but unlimited growth, whereas the dwarf shoots are borne by the long shoots and stop growing after some time. Depending on the species, each dwarf shoot has one to five needlelike leaves. The leaves are well-adapted for xeric habitat; they are covered by a thick cuticle, and have sunken stomata and a hypodermis of thick-walled cells Both the stem, roots and leaves possess numerous resin canals.

Fig. 8.1 A twig of pine showing a long shoot bearing dwarf shoots with needlelike leaves, and ← female cones of different ages. (*Courtesy: Dr. R. N. Konar, Department of Botany, University of Delhi.*)

Pines are monoecious, which means that the male and female reproductive structures, known as cones, occur on different branches of the same tree Male cones arise in clusters (Fig. 8.2A) in place of dwarf shoots Each cone consists of numerous microsporophylls, arranged spirally on the central axis (Fig 8.2B). Two microsporangia are present on the lower side of each microsporophyll (Fig. 8.2C). At maturity, the sporangia dehisce by a longitudinal slit, shedding large quantities of pollen grains (male gametophyte). The pollen grains are discharged as clouds of yellow powder, commonly referred to as "sulphur shower" At shedding, each pollen grain possesses two large wings hanging downwards A pollen grain consists of a large tube cell, a comparatively small antheridial cell and two degenerating

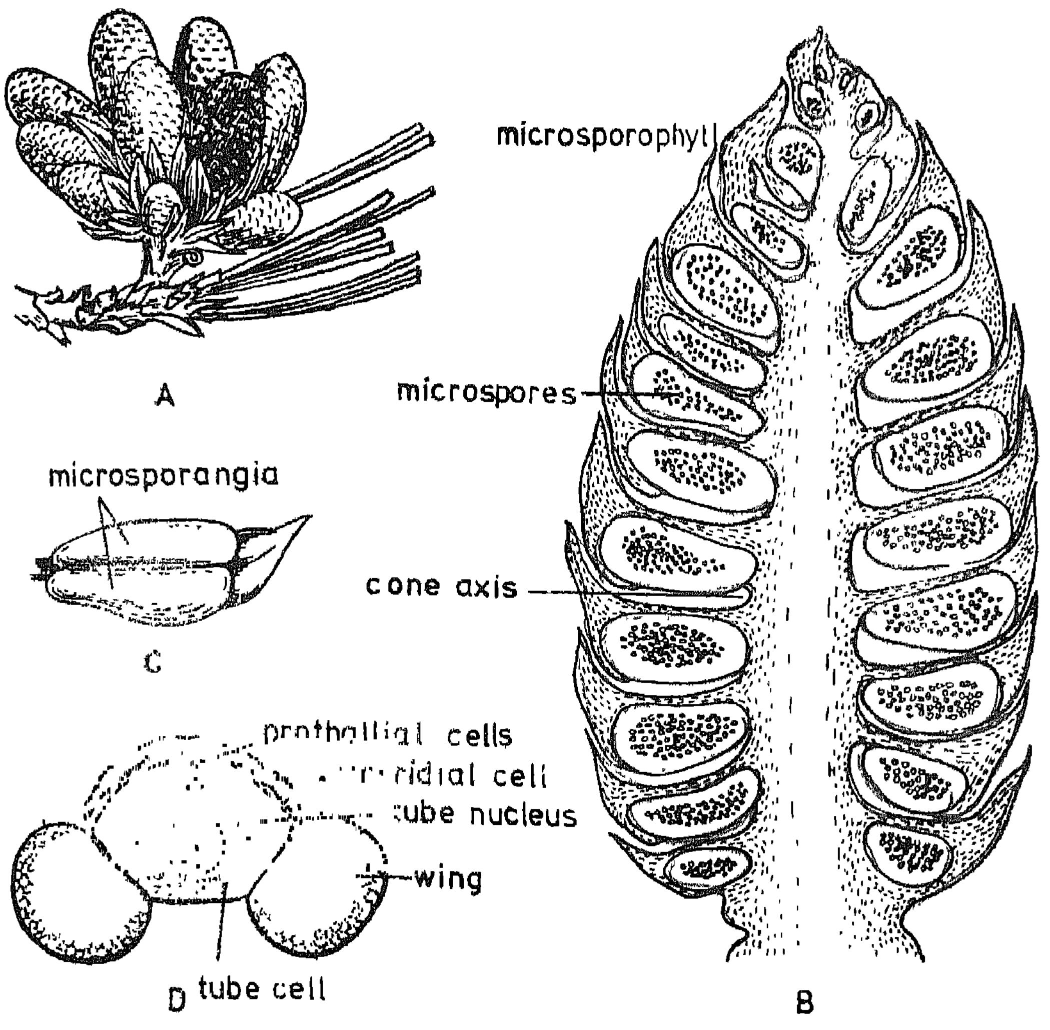


Fig. 8 2 *A*--A cluster of male cones; *B*--Longitudinal section of a male cone; *C*--Microsporophyll bearing two sporangia; *D*--Mature pollen grain (*Courtesy: Dr R. N. Konar, Department of Botany, University of Delhi.*)

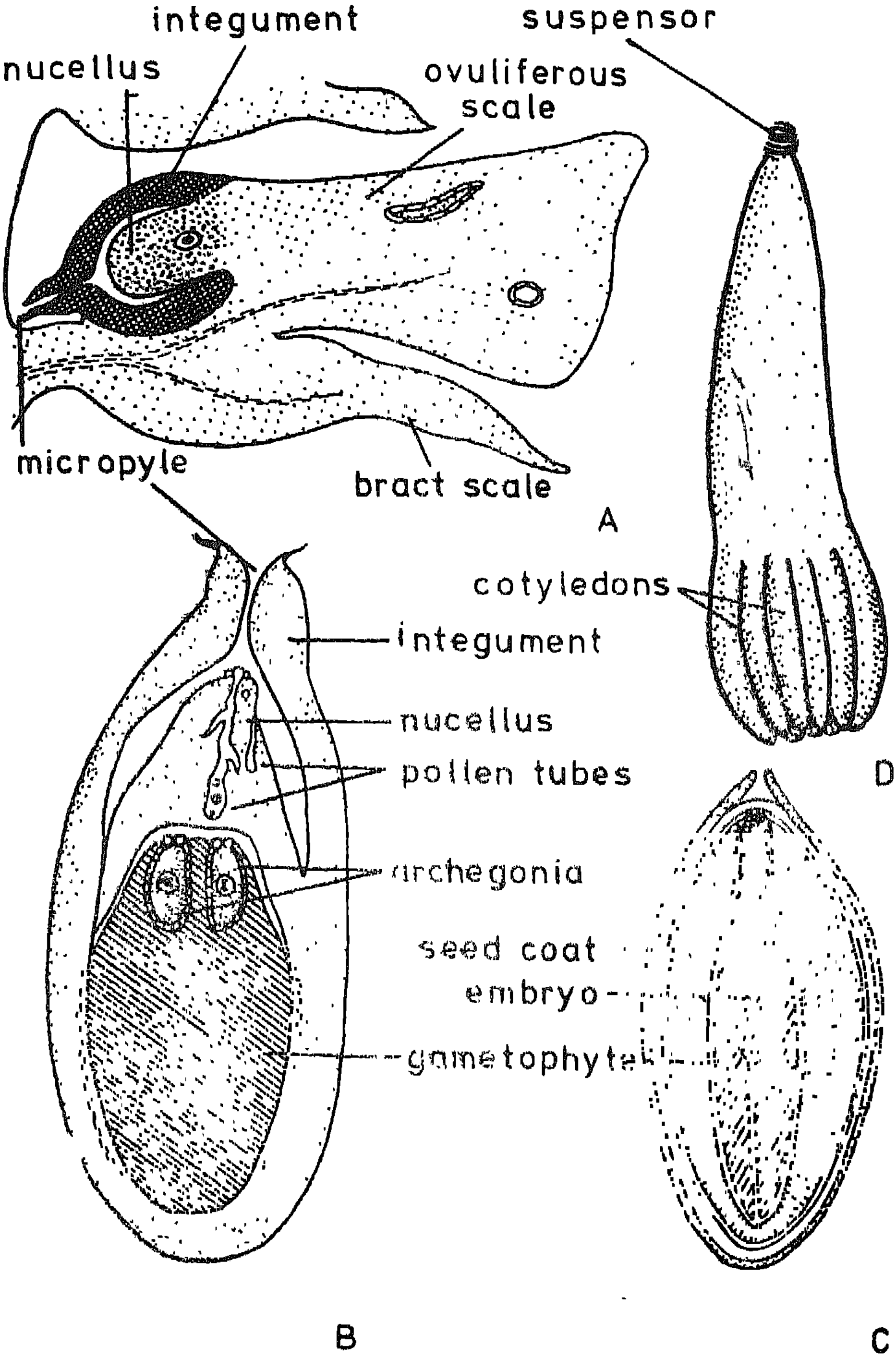


Fig 8.3 *A*—Longitudinal section of the bract scale and the ovuliferous scale, *B*—Longitudinal section of the ovule at the time of fertilization; *C*—Longitudinal section of a mature seed; *D*—A mature embryo.

prothallial cells (Fig. 8.2D). The pollen grains are haploid and represent the gametophytic phase.

Female cones are borne at the tips of long shoots (Fig. 8.1) and generally occur in pairs. Initially, the cone is small, elongated to round in structure and varies in colour from green to maroon. Each female cone consists of 80-90 bract scales borne spirally on the central axis. In the axil of each bract scale is present another flattened structure called the ovuliferous scale (megasporophyll). The two scales together constitute the seed-scale complex (Fig. 8.3A). On its dorsal surface, close to the central axis, each ovuliferous scale bears two ovules. The megasporophylls borne at the base and the apex of a female cone are sterile or non-functional. An ovule has three main components (Fig. 8.3B): (a) integument, (b) nucellus, and (c) female gametophyte. The nucellus is almost completely surrounded by a single integument which extends beyond it on one side in the form of a small tube, called the micropylar tube. The opening of the tube on the outside is called the micropyle. In the nucellus is embedded the massive female gametophyte. The nucellus has a megaspore mother cell which divides meiotically forming a row of four haploid megaspores. Of these, the lowermost spore develops into the female gametophyte, whereas the other three degenerate. The female gametophyte bears two to eight archegonia close to the micropylar end. A mature archegonium comprises an egg cell, a ventral canal cell (which degenerates before fertilization) and a neck composed of one or two tiers of four cells each.

At the time of pollination the ovuliferous scales become separated from each other, making sufficient space for the pollen to reach the ovule. The air-borne pollen are caught by the micropyle in a pollination drop secreted by the nucellus. After the pollen are trapped, the pollination drop is withdrawn and the pollen come to lie on the nucellus.

Soon after reaching the nucellus, the pollen germinate by giving out a pollen tube (Fig. 8.3B). The tube grows down through the nucellus for some time and then stops. Fresh growth of the tube is resumed after a year, when it pierces through the female gametophyte reaching the neck of an archegonium. The tube nucleus migrates into the pollen tube. The antheridial cell divides within the pollen grain giving rise to a spermatogenous cell and a stalk cell and both of these cells also move into the pollen tube. The spermatogenous cell divides, forming two male gametes. The tube forces its way through the neck and discharges its contents into the egg cell. One of the male gametes fuses with the egg nucleus, forming a diploid zygote. The other male gamete, the stalk cell and the tube cell gradually degenerate and disappear.

After fertilization, numerous changes occur in the ovule whereby it is transformed into a seed (Fig. 8.3C). The integument develops into the seed-coat with three distinct layers: (a) the outer fleshy layer, (b) the middle stony layer, and (c) the inner fleshy layer. The zygote develops into an adult embryo which looks much like a dicotyledonous embryo but has 3-18 cotyledons (Fig. 8.3D). The seed is furnished with a wing which is jointly formed by the outer layer of the integument and the basal part of the ovuliferous scale. The wing helps in seed dispersal.

When the seeds are fully mature, the central axis of the cone elongates and the scales open out (Fig. 8.4), facilitating the dispersal of the seeds.

The salient features of the life cycle of *Pinus* as representing the group Gymnosperms are:

1. Large, highly vascularised, woody plants
2. Sporophytic generation dominates the life cycle, and the gametophytes are borne on the sporophyte
3. Water as medium is not essential for fertilization.
4. Seeds are the unit of multiplication and dispersal
5. Nutrition for the development of embryo is provided by the female gametophyte.
6. Seeds are naked; they are not enclosed in the ovary or fruit wall

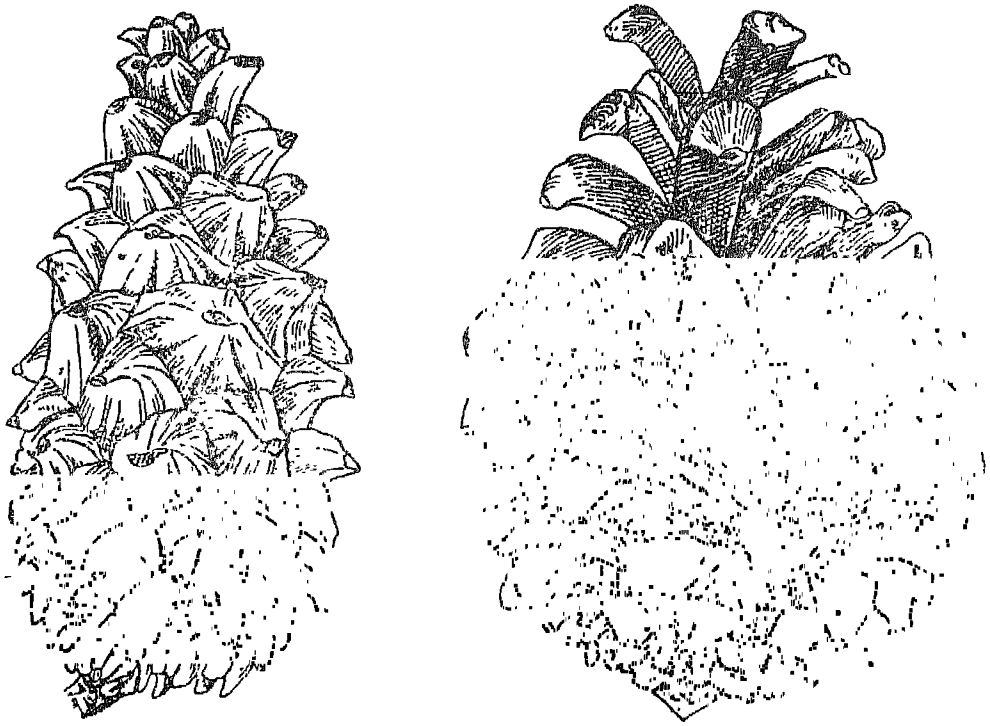


Fig 8 4 Three-year old female cones of *Pinus*. In the cone. on the right, the scales have opened out, and the seeds have been shed. (*Courtesy Dr. R N Konar, Department of Botany, University of Delhi.*)

EXERCISES

1. Describe the vegetative structure of a *Pinus* tree.
2. Compare the structure of microsporophyll and megasporophyll of *Pinus*.
3. What are the characteristic features of Gymnosperms?

4. What are the differences between a dwarf shoot and a long shoot ?
5. What changes occur in the ovule of *Pinus* as it develops into a seed ?
6. List the events from pollination to fertilization in the Gymnosperm that you have studied.
7. What do you understand by the following terms : (a) prothallial cell, (b) ovuliferous scale, (c) pollination drop, and (e) naked seed ?

CHAPTER 9

Seed

SEED is the final outcome of several life processes in a plant. It is also the beginning of a new generation. Seed represents a miniature plant with an adequate supply of reserve food material and devices for its protection. In the seed life activities are temporarily suspended in order to enable the plant to successfully pass through unfavourable and injurious climatic conditions. On return of favourable conditions, the seed resumes active life and grows into a full plant. This dormant phase of plant life serves the plant in another important way. In the form of seeds, a plant can be carried to long distances without special precautions and expensive means as are required for the transportation of sapling.

Structure

A fully developed seed contains an embryonic plant (with a primordial root and shoot), and is provided with reserve food materials and protective covering/s (seed coat/s). At maturity, the seed becomes dry and gets separated from the parent plant. The seed may remain dormant for prolonged periods and germinate to form new individuals when conditions are favourable.

Seeds can be as small as fine sand particles, as in orchids (about two million seeds per gram), or as large as pumpkins, as in the double coconut (*Lodoicea sechellarum;* fresh weight per seed about 6 kg). The seed surface may be smooth or variously patterned. In certain plants, the seeds are so characteristic that they form a reliable means of identification of a species or even a variety.

To describe the structure of a mature seed we shall consider pea (*Pisum sativum*) as an example (Fig. 9.1). A mature pod of pea has a number of seeds arranged in two rows (Fig. 9.1A). The seeds are attached to the fruit wall by a small stalk, the funiculus (Fig. 9.1B). At maturity, the funiculus becomes detached, leaving a scar called hilum (Fig. 9.1C). Slightly below the hilum is located a small pore, the micropyle (Fig. 9.1C). During seed germination, water is absorbed mainly through this pore. The seed has generally a smooth seed coat which can be easily removed after soaking it in water overnight. In some plants, such as the castor bean (*Ricinus communis*), the seed coat shows two distinct layers: the outer layer called testa and the inner layer called tegmen. In pea, these layers cannot be distinguished

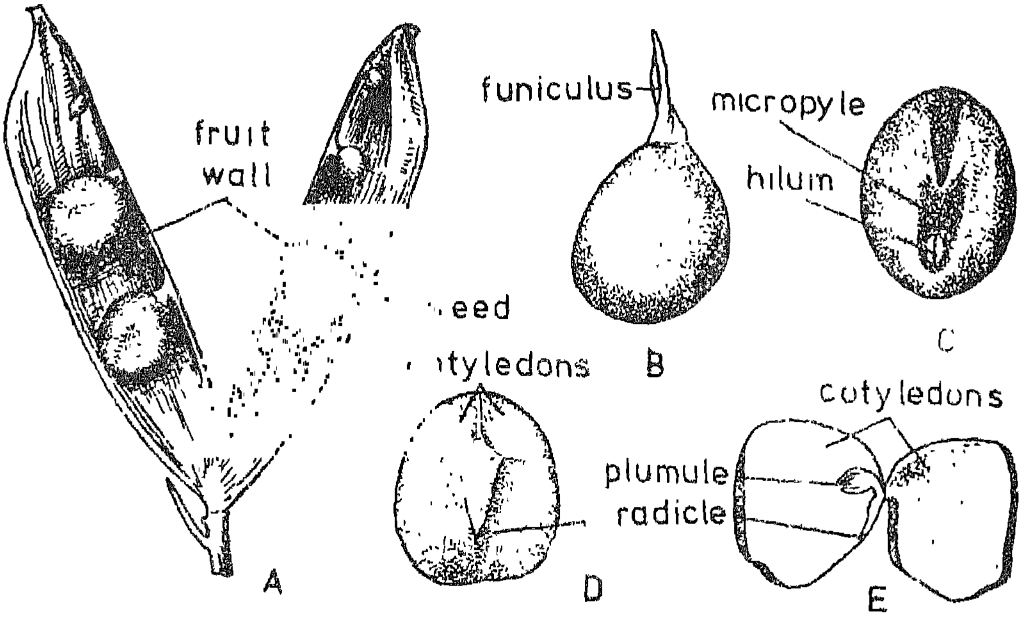


Fig. 9.1 Parts of a pea seed. *A* -Open pod bearing three well-developed seeds; some abortive seeds are also present. *B*—Detached seed along with the funiculus; *C*—Seed showing the hilum and micropyle (after the removal of funiculus), *D*—De-coated seed: note the two massive cotyledons and the radicle, *E*—Cotyledons separated apart to show the entire embryonal axis. (*After S S. Bhojwani and S P Bhatnagar*, 1975, *The Embryology of Angiosperms, Vikas Publishing House Private Limited, Delhi.*)

clearly. Upon removing the seed coat, two massive and deep-green cotyledons are seen (Fig. 9.1D) They are attached laterally to the embryonal axis (Fig 9.1E). A portion of the embryonal axis projects beyond the cotyledons, the pointed end of which is the embryonal root, technically called radicle. The other end of the axis, which is the embryonal shoot or plumule, is seen only when the two cotyledons are separated (Fig. 9.1E). The portion of embryonal axis between the radicle and the point of attachment of the cotyledons is called the hypocotyl, whereas the portion of the embryonal axis between the plumule and the cotyledons is termed epicotyl. The embryonal axis and the cotyledons together constitute the embryo.

In pea, the reserve food material is stored in the massive cotyledons and the seed lacks a special nutritive tissue, the endosperm. All such seeds which lack endosperm at maturity are called non-endospermous or ex-albuminous On the other hand, in several other plants such as castor bean, coconut and cereals (Fig. 9.2), food is stored in the endosperm. Such seeds in which the endosperm persists and nourishes the seedling during the initial stages are called endospermous or albuminous.

On the basis of the number of cotyledons in the embryo, the angiosperms have been divided into two large groups: (1) dicotyledons, having embryos with two cotyledons, and (2) monocotyledons, with only one cotyledon

Grasses and cereals are monocotyledons but their seeds show such striking features

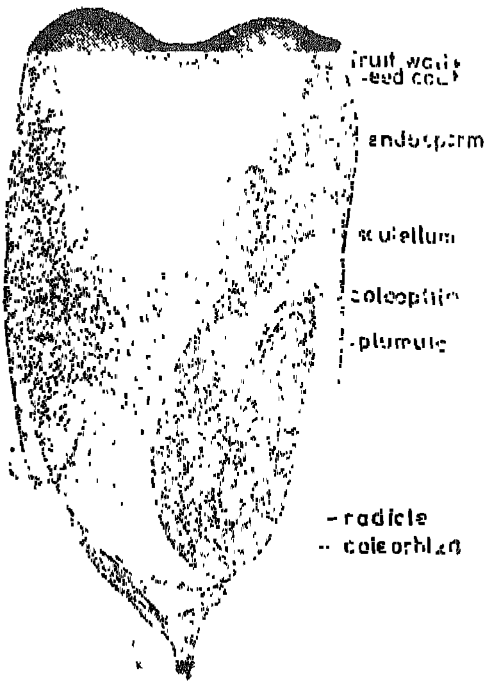


Fig. 9.2 Longitudinal section of a mature maize grain.

that they deserve special treatment. Here we shall consider maize as an example (Fig. 9.2). A maize grain is a single-seeded fruit in which the seed coat and the fruit wall are inseparable. Externally, you would see an oval, white region on one side of the grain. The embryo is enclosed in this portion. In the longitudinal section of a grain, as seen in Fig 9.2, the embryo lies on one side of the massive endosperm. Cells of the outermost one to three layers of the endosperm are called aleurone cells or aleurone tissue. They contain abundant protein. During seed germination, some of the enzymes required are synthesised by utilizing the protein present in the aleurone cells. Like other monocotyledons, the corn embryo has a single cotyledon attached laterally to the embryonal axis. In cereals, the cotyledon is called the scutellum. It has a secretory epidermis in contact with the endosperm. The portion of the embryonal axis below the cotyledon is the radicle which is covered with a special sheath of tissue called the coleorhiza. Above the point of attachment of the cotyledons, the embryonal axis is enclosed by a leaflike membranous structure, the coleoptile. The cone-shaped coleoptile has a pore at the apex through which the first foliage leaf emerges during germination.

Besides the basic structures — endosperm, embryo and seed coat—certain special structures may arise during seed development In castor bean and several other related plants a fleshy whitish tissue is formed at one end of the seed (Fig. 9.3), which is called caruncle. It is derived from the outer integument. The juicy edible part of the litchi fruit is an outgrowth of the funiculus that develops after fertilization. It covers the seed and is named aril.

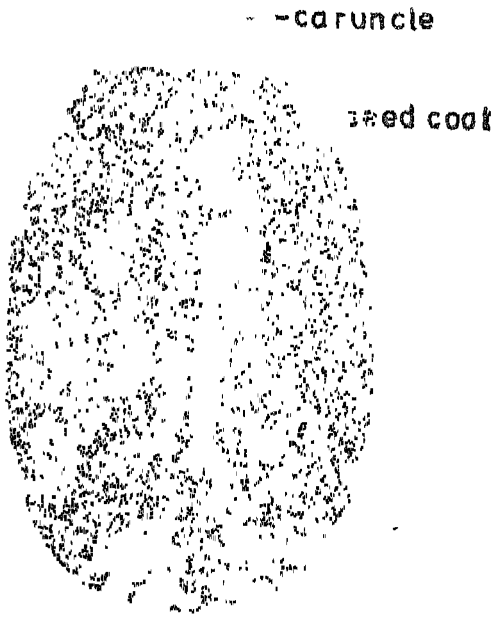


Fig. 9.3 A castor bean seed showing a prominent caruncle.

The cotton fibres of commerce are the elongated epidermal cells of the seed coat They are single-celled and thin-walled These fibres attain a length up to 45 mm and have characteristic twists.

Commonly, the endosperm surface is smooth but in some plants, such as areca nut, *Passiflora* and *Antigonon*, it may show deep furrows. Mature endosperm with any degree of irregularities and unevenness of its surface contour is called ruminate. A clear picture of the rumination can be had by looking at a transverse section of the seed of *Areca*

Importance of Seed

During evolution, the development of the seed habit gave the land plants a unique advantage for dispersal and survival. For man the discovery of the use of seed formed the basis of agriculture. By sowing the seeds of cereals in the river valley under sunshine, the neolithic man was able to ensure a regular supply of food for himself. Agriculture, thus, liberated man from the drudgery of food gathering, and it is believed that this was essential for his becoming civilized. Unlike other resources used by man which are exhaustible (like coal, metals, etc), man can have an assured supply of a wide variety of plants to fulfil his needs.

For most annual plants, seeds are the only means of multiplication and continued existence These plants live for a few months and survive in the form of seeds until conditions for germination become favourable the following year.

Seed is an important means for establishing a species in a new area. Most of the plants being rooted at one place, nature has provided seeds with features to overcome this disadvantage. They can get detached from the parent plant and distribute themselves far and wide Seeds have special devices for dispersal by wind, water, or animals For example, the seeds dispersed by air are generally very light (as in orchids); they may develop wings (as in *Tecoma*, *Cinchona* or hair (as in cotton, milk-weeds, Fig. 9.4). The unit of dispersal could also be a fruit which may have special devices of its own.

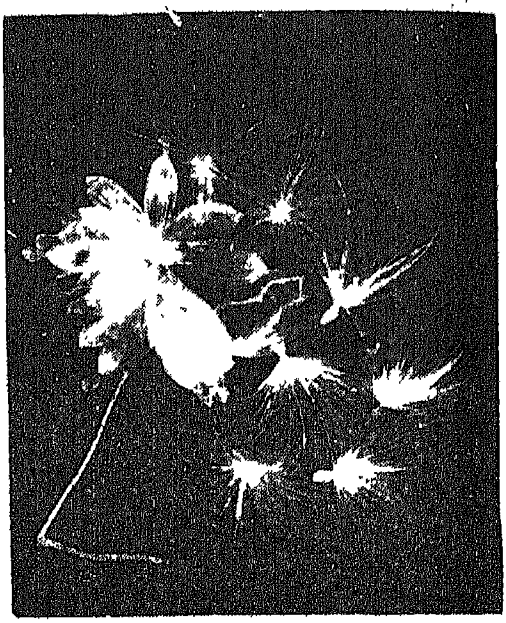


Fig. 9.4 Hairy seeds escaping from a dehisced fruit of *Pergularia*

Cereals and legumes constitute a major part of human diet Seeds are also sources of several items of human use, such as fibres (cotton), oil (mustard, groundnut, coconut), beverages (coffee, cocoa), and spices (cardamom, mustard)

Seed Dormancy and Germination

In plants such as *Rhizophora*, a typical mangrove plant, the growth from zygote to embryo and then to the seedling is almost continuous The newly formed seeds germinate while they are still enclosed within the fruit and are attached to the parent plant. This phenomenon, known as vivipary, is of rare occurrence

The seeds of pea, bean, maize and of a large number of domesticated plants are capable of germinating immediately after they are harvested, provided suitable conditions like water, oxygen and light are available In some other plants, a freshly formed seed is incapable of germination even under conditions normally considered favourable This natural barrier for development, which is gradually overcome with time, is described as dormancy The period of dormancy varies considerably with the species Rarely, the seeds of the same plant may show variation in their dormancy period. Seed dormancy is of special significance to plants, as it prevents the germination of seeds under conditions adverse for the survival of their seedlings. Seed dormancy can be due to any of the following causes :

1. *Under-developed embryos :* In plants like *Ginkgo biloba* and *Eranthis hiemalis* (Fig. 9 5) the embryo is not organized when the seed is shed and attains full development before it germinates

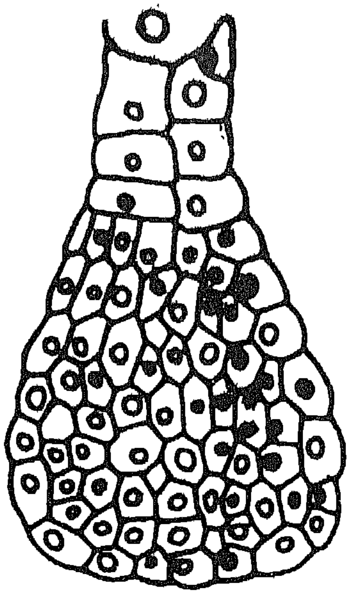


Fig 9.5 Pear-shaped, undifferentiated embryo excised from a freshly harvested seed of *Eranthis hiemalis.*

2. *Impermeability of the seed coat* Examples of very hard seed coats that prevent uptake of water and oxygen are *Trigonella* and *Xanthium*, respectively.
3. *Inhibitors* Accumulation of certain inhibitory substances in the tissue of the seed or fruit may prevent seed germination. Tomato juice inhibits the germination of tomato seeds because of the presence of ferulic acid. Inhibitors may be present in the embryo *(Xanthium)*, endosperm *(Iris)* or in the seed coat *(Cucurbita)* Abscisic acid is one of the most commonly detected inhibitors of germination.

Under natural conditions seed dormancy is gradually overcome by processes such as weakening of the seed coat by the digestive juices in the alimentary tract of fruit-eating birds and other animals, or in the soil due to the action of microbes, or due to mechanical abrasions. Alternatively, the inhibitors may be inactivated by heat or cold or washed off by rain, or counteracted by growth hormones synthesised towards the end of the dormancy period. Experimentally, dormancy of seeds can be broken by rupturing the seed coat, or by treating the seeds with concentrated sulphuric acid. Soaking the seeds in certain chemicals like potassium nitrate, ethylene chlorohydrine, thiourea or in certain plant hormones is known to break dormancy

Factors for Seed Germination

Water, oxygen, temperature and light are factors that promote seed germination. Tissues in a mature seed are highly dehydrated and the availability of external water is the prime requisite for seeds to initiate activities necessary for seed

germination. Temperature requirement of seeds varies depending on the species. The seeds of tropical plants require much higher temperatures as compared to those of temperate ones. Except for the seeds of aquatic plants and of such plants as rice, most seeds require good aeration for germination. Light promotes germination of some seeds *(Digitalis purpurea, Epilobium hirsutum, Lactuca sativa, Lepidium sativum)* but inhibits it in others *(Nigella, Phacelia, Phlox)*. The wavelength of visible light which stimulates germination is in the red region. Far-red light reverses this effect. Light sensitivity of seeds is due to the presence of a pigment called phytochrome

In obligate root parasites, such as *Orobranche*, seed germination is dependent on a stimulus (substances present in the exudate) from the roots of the host

The Process of Germination

The first visible indication of germination is the swelling of seeds by absorption of water. For all practical purposes, the emergence of the radicle or plumule through the seed coat is taken as the criterion for seed germination. However, before germination can be actually seen, several intricate physiological processes must occur within A rapid increase in respiration occurs This is preceded or

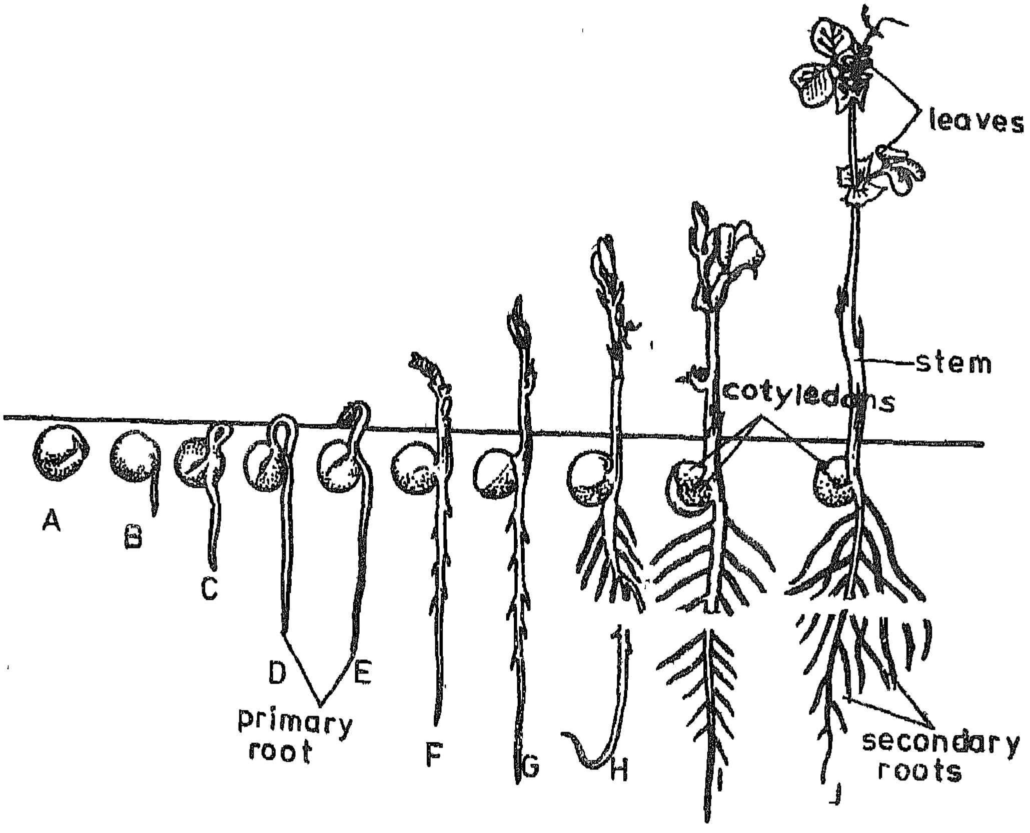


Fig. 9.6 Stages in the germination (hypogeal) of pea seed. Note that the cotyledons have remained underground.

accompanied by the appearance of some hydrolytic enzymes that break down food materials stored in the seed to simpler molecules that can be utilized by the seedling until the latter can become photosynthetically efficient.

Based on the behaviour of the cotyledons, germination is broadly divided into two types. If the cotyledons stay below the soil, germination is described as hypogeal (gram, pea, Fig 9.6) and if they are carried above the soil, the germination is said to be epigeal (bean, castor bean, cotton, tamarind, Fig 9 7) Germination is hypogeal in all monocotyledonous plants The various types of germination are illustrated in figures 9 6, 9.7 and 9.8

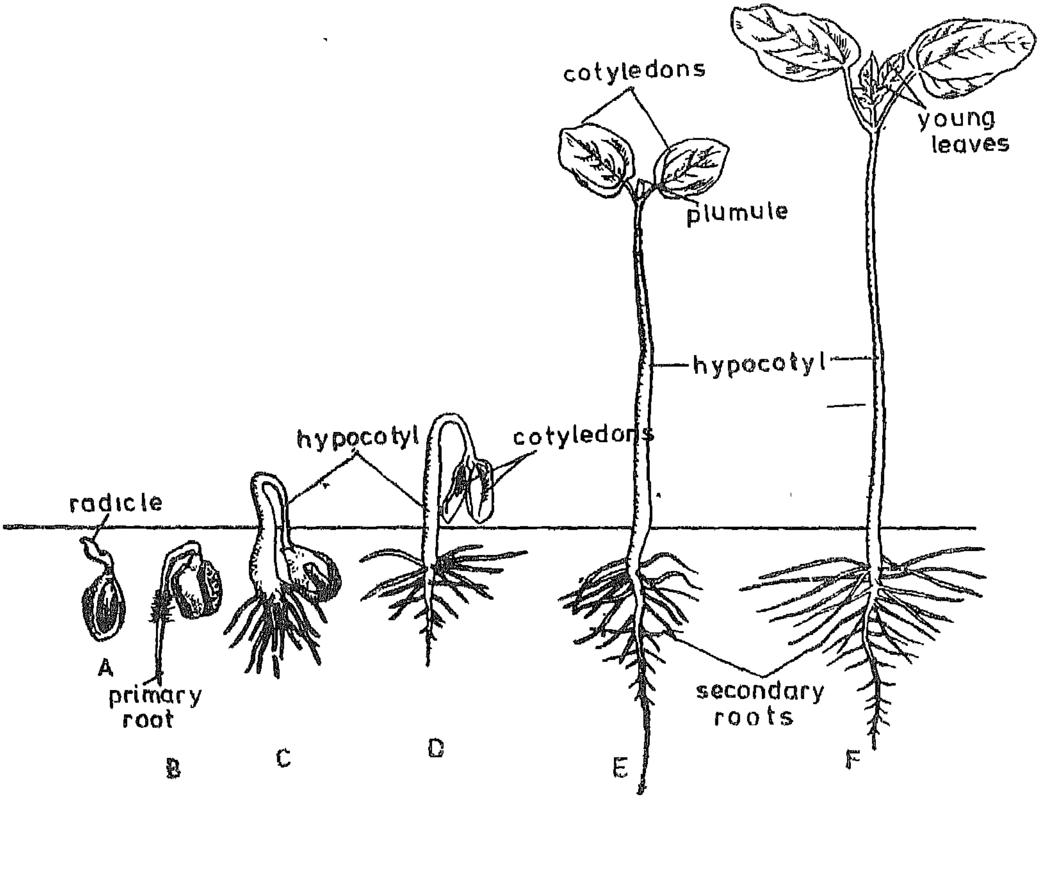


Fig. 9.7 Stages in the germination (epigeal) of castor bean seed. Due to the elongation of hypocotyl, the cotyledons are carried above the soil surface.

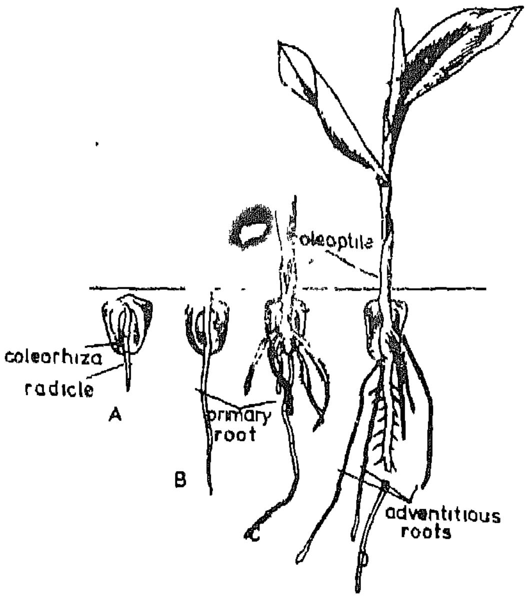


Fig. 9.8 Stages in the germination (hypogeal) of maize grain. Unlike the condition in castor bean, in cereals the primary root does not form the main root system. Adventitious roots originate close to the primary root and develop into the extensive fibrous root system.

EXERCISES

1. With the help of suitable diagrams, explain the structure of the seed of pea and show how it differs from that of castor bean and of *Pinus*.
2. What is seed dormancy ? What is its biological significance ?
3. Cite two examples each of endospermous and non-endospermous seeds.
4. On the basis of the structure of the embryo, how would you identify whether a given sample of seeds belongs to a monocotyledonous or a dicotyledonous plant.
5. What are the various part of a seed in which food is stored ? Give suitable examples for each.
6. Explain the following terms : (a) vivipary, (b) endosperm, (c) scutellum, (d) ruminate endosperm, and (e) aleurone cells.

CHAPTER 10

Juvenility and Heteroblastic Development

AFTER germination, a young plant undergoes vegetative growth for some time but lacks the capacity to form flowers. This early phase of plant development has been termed the juvenile phase. The juvenile phase can be recognized from the adult phase by certain features such as leaf shape, habit of the stem and the size of the thorns if present. Some marked differences between the juvenile and adult stages are also known to occur in a few lower plants

The change from the juvenile to the adult phase is gradual as exhibited by increased lobing of the lamina in the leaves of cotton, *Delphinium* and *Ipomoea* (Fig. 10.1), or it may be abrupt. The latter condition is said to represent heteroblastic development. For example, in some plants the first few leaves are normal, whereas the subsequent leaves may be phyllodes (*Acacia* sp.), or spines *(Europaeus)* or tendrils *(Lathyrus aphaca)*. Similarly, in the pines the leaves that appear just after the expansion of the cotyledons are needlelike. As the plant ages, the shoot apex produces small, brownish and scalelike leaves.

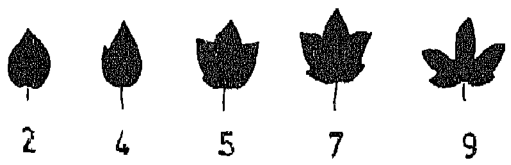


Fig. 10.1 Showing changes in the leaf shape at successive nodes (from the base to the top) in *Ipomoea caerulea*. (*After E Ashby*, 1948, *New Phytologist*, *Vol.* 47.)

In *Hedera helix* (ivy), a classical example of heteroblastic development (Fig 10 2), the juvenile phase is characterized by climbing habit and alternate, palmately lobed leaves. The adult features, such as erect or semi-erect branches and entire leaves borne oppositely, develop only when the plant begins to flower.

There is evidence that the juvenile and adult parts of the plants are also physiologically different In the juvenile phase, the plant does not respond to stimuli that can induce flower formation. In woody plants, branches cut from the juvenile stage root more readily than those derived from the adult stage This feature is of

great importance in the practice of vegetative propagation

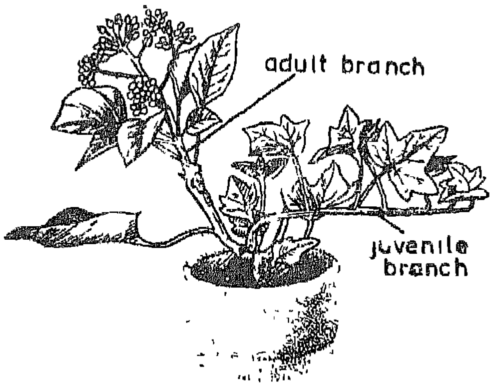


Fig. 10.2 *Hedera helix* (English Ivy) plant bearing juvenile (with lobed leaves) and adult (with entire leaves) branches. (*After J. Janick* 1972, *Horticultural Science, W. H. Freeman and Company, San Francisco.*)

In perennial plants, both phases of development may occur on the same individual, and the cuttings taken from different parts maintain the characteristics of their phase. For example, cuttings taken from reproductive branches of the ivy plant would give rise to small bushes which are quite different from the climbing vegetative plants. Similarly, buds from the lower juvenile portion of the seedling trees of pear, apple or citrus will produce nursery trees that are vigorously growing, thorny and slow to flower, whereas buds from the upper portion of the same tree would form plants that are less vigorous, smooth barked and quick to flower.

Heteroblastic development may be genetically controlled. Several external and internal factors are also known to induce such development. In several aquatic plants, heteroblastic development is well illustrated; the juvenile leaves are submerged and finely dissected, whereas the adult leaves are floating or aerial and much less dissected (*Ranunculus aquatica*, *Limnophila heterophylla*) In species such as *Alisma plantago-aquatica* and *Sagittaria saggitifolia*, the juvenile phase can be prolonged indefinitely by maintaining the plants under deep water, or supplying them with low intensity light. The adult leaves arise only when normal light intensity is provided. It can be shown experimentally in some pteridophytes that sugar deficiency causes the juvenile type of growth.

To some extent, growth substance also influence the developmental pattern. Adult plants of ivy, treated with gibberellin (GA), show vigorous vegetative growth, and sometimes juvenile branches also appear. Similarly, the juvenile phase in *Ipomoea caerulea* could be prolonged by GA-treatment of the seedlings. However, GA cannot be regarded as a specific juvenile hormone because in *Eucalyptus* seedlings GA-application brings about early appearance of adult leaves as compared to the untreated seedlings.

EXERCISES

1. Trace the changes occurring in a juvenile shoot as it becomes transformed into an adult shoot.

CHAPTER 11

Flower

THE SHOOT tip of a young plant grows vigorously and bears only foliar leaves. This is the vegetative phase. At a certain stage, which varies with the species or even the variety, the plant switches over to the reproductive phase. The vegetative phase, which is specific for each plant, lasts only a few weeks in chickweed *(Stellaria media)* and about six months in tobacco. These and all other plants which go from seed to seed in one season or year are known as annuals. The plants such as cabbage, beet, and carrot, normally grow vegetatively for one season and flower in the following season. Thus, they require two seasons to complete their life cycle and are described as biennials. Most trees are perennials. They take a few years to begin to flower but bear flowers year after year. Agave, certain palms and bamboos flower only once in their life time. Such plants are termed monocarpic. In these plants, flowering and fruiting result in the death of the individual

Morphologically, the flower is a modified shoot in which the internodes are highly condensed, and the leaves are specialized to suit the different functions. During floral initiation, the shoot apex directly becomes transformed into a reproductive apex It may give rise to a single flower, as in tulip and poppy, or develop into an inflorescence, as in wheat, sunflower and *Antirrhinum*. The vegetative apex is conical, whereas the reproductive apex is comparatively flat and wide. Unlike the vegetative apex which shows a repetitive pattern of growth by forming leaves, buds and stem tissue, the floral apex forms appendages of different types in a predetermined sequence—sepals, petals, stamens and carpels. The axis that bears floral organs is known as the receptacle. Usually, there is no elongation of the internodes on the receptacle, and the various floral whorls differentiate close to each other.

Flowers exhibit a great deal of variation in size, shape, colour and arrangement of floral appendages on the receptacle.. The duckweed, *Wolffia microscopica,* has the smallest flower, about 0.1 mm in diameter. The largest flower (up to a metre in diameter) is found in certain species of *Rafflesia*, a root parasite native to the forests of Malayasia. The colour of a flower is usually due to the showy petals which exhibit many variations. Despite wide variations in shape, the basic organization of the flower is fairly uniform.

Flower Formation

The switch-over from the vegetative phase to the reproductive phase is controlled by a variety of internal and external factors. These factors influence only floral initiation, and once the initiation has occurred, further differentiation of the flower is largely independent of these factors.

The external conditions necessary for inducing flowering are called inductive conditions, and the duration for which these conditions are required is termed inductive period. Further, the external conditions under which the plant maintains vegetative growth for an unlimited period are called non-inductive conditions

One of the important conditions necessary for flowering is what is described as ripeness to flower. Until this stage is reached, the plant cannot flower even under inductive conditions. The number of leaves on a plant is one of the criteria for determining ripeness to flower. There seems to be a minimal leaf number for a plant before it can be induced to flower. This number varies with the species In the classical example of *Xanthium*, eight leaves must be present before the plant can show the flowering response. Rarely, as in ***Pharbitis nil*** (Japanese morning glory) and ***Chenopodium rubrum*** (pigweed), the plants come to flower even at the cotyledonary stage under inductive conditions.

The number of hours in a day during which light (photoperiod) is received by a plant is an important factor in flower induction. This phenomenon is described as photoperiodism. Three major groups of flowering plants have been recognised on the basis of their light requirement to initiate flowering. These are called Long-Day Plants (LDP), Short-Day Plants (SDP) and Day Neutral Plants (*see* Chapter on Plant Growth and Development)

It has been demonstrated experimentally that the site of perception of the light stimulus for flowering is generally the leaf. This can be easily demonstrated. If all the leaves of a plant are removed before subjecting it to the right light conditions, it would fail to bloom. On the other hand, retention of a single leaf or a minimal part thereof will enable it to perceive the light stimulus. Under appropriate light conditions, the leaves synthesise a flowering substance, presumably a hormone of an unknown nature, and transfer it to the shoot apices where floral differentiation occurs Apparently, the flowering hormone is similar in nature in both LDP and SDP If a branch from a SDP, after floral induction, is grafted on to a non-induced LDP, the former is able to induce flowering in the latter

A period of low temparature (0-15°C) is required by some plants to initiate flowering (cabbage, rye grass, foxgloves, etc.) This phenomenon is known as vernalization. Unlike photoperiodism, the site for perceiving the vernalization stimulus for flowering is the shoot apex itself. For most plants requiring vernalization, an appropriate photoperiod is also necessary for flowering *(Secale cereale, Hyoscyamus niger, Streptocarpus).*

The photoperiodic and vernalization requirements for flowering can often be substituted by certain known growth substances, and the plant brought to flower under non-inductive conditions. Gibberellic acid has been successfully employed to induce flowering in long-day plants under short-day conditions. It also fulfils the vernalization requirement for flowering in some species. Similarly, cytokinins are known to replace short-day requirements. The knowledge of physiology of flowering in a species and the artificial induction of flowering under non-inductive conditions is of immense practical importance in agriculture. With this background knowledge,

it is now possible to cross plants which normally come to flower at different times of the year Also, several ornamental flowers can now be procured throughout the year.

Sex Expression

As indicated earlier, a flower may be bisexual, male or female. The sexual nature of flowers and the distribution of male and female flowers is a genetically fixed character for a species In dioecious species, there may be a chromosomal basis of sex determination *(Coccinia)*. The male and female plants also exhibit differences in endogenous levels of growth substances. For example, plants of *Cucumis* which bear mostly male flowers (andromonoecious) have a higher gibberellin content as compared to those which bear only female flowers (gynoecious). The exogenous application of gibberellin can also induce the formation of male flowers in genetically female plants. Similarly, treating male plants with auxin or ethylene induces the formation of functionally female flowers suggesting the involvement of growth substances in sex differentiation. The same responses have also been shown in *Cannabis sativa* which is dioecious. The most enigmatic and intriguing aspect of differentiation is the formation of male and female sex organs from tissues lying so close on the receptacle of a bisexual flower.

EXERCISES

1. Which plant has the smallest flower and which one has the largest ?
2. How would you distinguish a vegetative shoot apex from a reproductive apex ?
3. With reference to flowering, what do you understand by the terms "inductive period" and "inductive conditions"?
4. Which part of the plant usually perceives the light stimulus for flowering ? How would you establish it experimentally ?
5. How would you induce male flowers on a female plant and female flowers on a male plant of *Cannabis ?*
6. On the basis of distribution of sex, how many types of flowers are known ?
7. Explain the following terms : (a) vernalization, (b) ripeness to flower, and (d) monocarpic plants.

CHAPTER 12

Sexual Reproduction

SEXUAL reproduction involves the fusion of a male and a female gamete. Pollen grains, which contribute the male gametes (sperms), are formed within the anther. The ovules, which bear the female gametes (eggs), are present in the ovary

The mature anther dehisces to liberate the pollen grains. These either drop on the stigma of the same flower or are transported to the stigma of another flower through an external agency such as wind, water, or insects Upon reaching the right stigma, a pollen grain germinates by putting out a pollen tube which grows through the stigma and style. After entering the ovary, the pollen tube finds its way into an ovule and releases the male gametes into the embryo sac. We shall first study the development of male and female gametes and then examine the process of fertilization.

Anther

The anther generally has four sporangia and a central column of sterile tissue called the *connective* (Fig 12 1). On either side of the connective is an elongated anther lobe. Each lobe has two microsporangia separated by a strip of sterile tissue.

A very young anther comprises a homogeneous mass of cells limited by a well-defined epidermis. During its development, the outline of the anther becomes four-lobed. In each lobe, a few hypodermal cells become enlarged and show conspicuous nuclei. These cells constitute the archesporium. The cells of the archesporium divide in a plane parallel to the outer wall of the anther (periclinal division), cutting-off parietal cells towards the periphery and sporogenous cells towards the interior of the anther. Cells of the parietal layer undergo a series of periclinal divisions to form 2-6 concentric layers of the anther wall. In the mature anther, the wall comprises the epidermis, a hypodermal layer of endothecium, 2-4 middle layers, and the single-layered tapetum (Fig. 12.1). Cells of the endothecium develop fibrous thickenings, except at the junction of the two sporangia. This layer helps in the dehiscence of the mature anther. Cells of the middle layer are ephemeral. Tapetal cells are large and have densely staining cytoplasm. These cells may be multinucleate or may have a large polyploid nucleus. Of all the wall layers, the tapetum is the most active physiologically and metabolically. The chief function

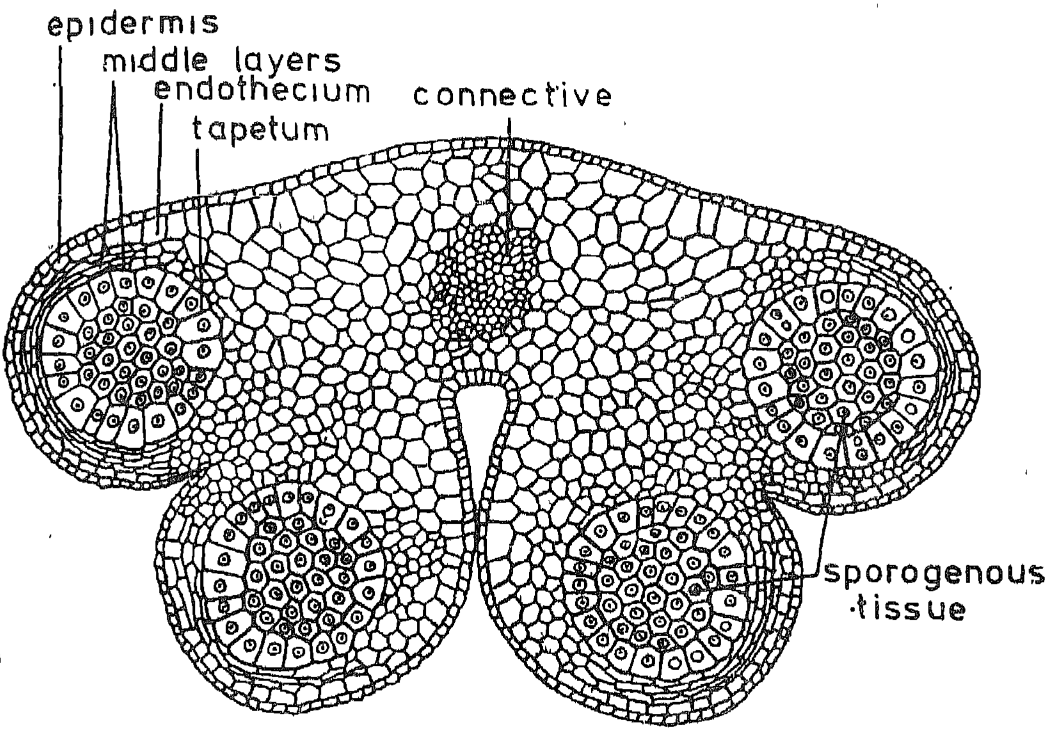


Fig 12.1 Transverse section of a four-sporangiate anther to show the various tissues. (*After S S. Bhojwani and S. P. Bhatnagar, 1975, The Embryology of Angiosperms, Vikas Publishing House, Pvt. Ltd, Delhi.*)

of the tapetum is the production and transport of enzymes, hormones and nutrients necessary for the development of pollen. The pollen wall material is partially synthesised in the tapetum. Abnormal development of the tapetum results in pollen sterility, indicating an intimate relationship between the tapetum and the pollen development.

The sporogenous cells may function directly as microspore mother cells (MMC) and undergo meiosis. Alternatively, the cells of the sporogenous tissue may undergo a few mitotic divisions to add up to their number before entering meiosis. Each microspore mother cell (MMC) has two sets of chromosomes and is, therefore, diploid. By a single meiotic division, each MMC gives rise to four haploid microspores. Initially, all the four spores remain enclosed in a common wall made of callose (Fig. 12.2). This four-celled organization is called *tetrad*. Usually, the arrangement of the microspores in a tetrad is tetrahedral or isobilateral but sometimes decussate, linear or T-shaped tetrads are also formed.

A mature microspore is called a *pollen grain* The pollen grain wall (Fig. 12.3) is highly specialized. It comprises two principal layers: the inner intine and the outer exine. The latter comprises many sublayers. The intine is pecto-cellulosic in nature, like the walls of other somatic cells. The exine, on the other hand, is chiefly made up of sporopollenin which

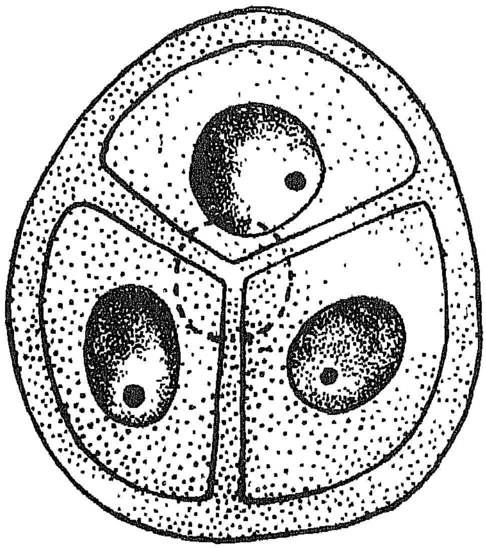


Fig. 12.2 A tetrahedral microspore tetrad. Three spores are seen in one plane. The fourth, which is behind, is shown with dotted lines.

is resistant to chemical and biological decomposition. In insect pollinated species,

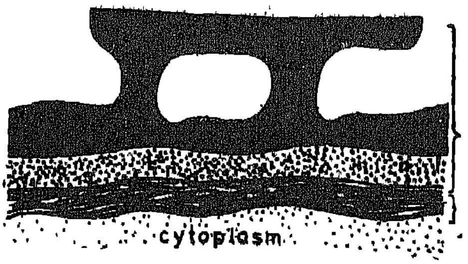


Fig. 12.3 A highly enlarged diagram showing the various zones of the mature pollen wall.

the exine is covered by a yellowish viscous and sticky substance called pollenkitt material. The surface of the exine is variously sculptured, and the ornamentation is often so characteristic that it can be helpful in identifying a species. At one or more places, the exine is very thin. These regions are known as germpores, through which the pollen tube grows out during pollen germination.

A freshly formed microspore is rich in cytoplasm and has a prominent, centrally placed nucleus. Soon after its release from the tetrad, the microspore undergoes rapid expansion. The nucleus moves to the periphery where it divides to form a large vegetative cell towards the centre and a small generative cell towards the wall (Fig. 12.4A). When formed, the generative cell is attached to the pollen wall but it eventually gets detached and comes to lie freely in the vegetative cell (Fig. 12.4B). In a large majority of flowering plants, pollen is shed at the two-celled stage. However, in plants such as cereals, the generative cell divides to form two male gametes, while the pollen is still within the anther. In those cases where pollen is shed at the two-celled stage, the generative cell divides after the pollen has landed on the stigma or upon its germination.

Pollen grains are usually disseminated individually. Rarely, however, they may be shed as tetrads. In milk-weeds, the pollen grains of each anther lobe are agglutinated into a saclike structure, the pollinium. Each anther has a pair of pollinia. Two pollinia, each belonging to two adjacent anthers, become attached to form the translator apparatus (Fig 12.5). A pollinating insect carries the entire apparatus.

At maturity, the anther commonly dehisces by a long slit in the middle of each lobe. The anther may also dehisce by means of short slits, pores and chinks.

Several types of air-borne pollen are the cause of bronchial allergy. You might have met some persons who suffer from the attacks of asthma in certain seasons of the year only. You may be curious to know that these periods coincide with the flowering of certain wind-pollinated plants. Specialists have shown that inhalation

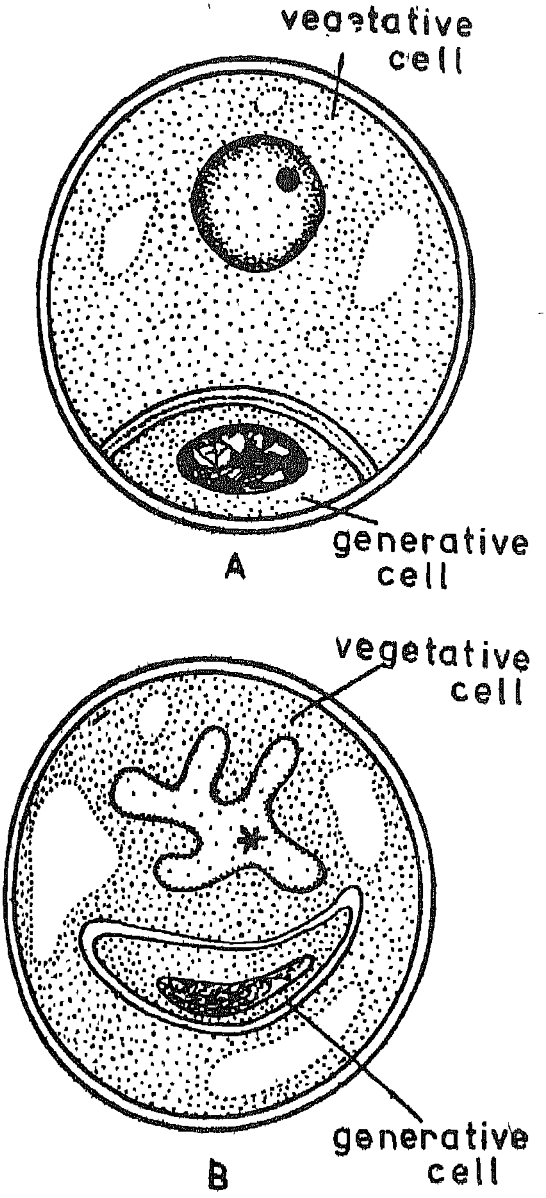


Fig. 12.4 *A*—A two-celled pollen grain with a large vegetative cell and a small generative cell attached on one side; *B*—Same, at a later stage, the generative cell has got detached from the pollen wall and has come to lie free in the cytoplasm of the vegetative cell. (*After S. S. Bhojwani and S. P. Bhatnagar*, 1975, *The Embryology of Angiosperms, Vikas Publishing House, Private Limited, Delhi.*)

of certain air-borne pollen may cause this condition. Different individuals may be sensitive to the pollen of different plants. By surveying the pollen population in the atmosphere, pollen calendars can be prepared and patients treated accordingly. Some of the plants in India producing allergenic pollen are *Amaranthus spinosus, Chenopodium album, Prosopis juliflora,* and *Sorghum vulgare*.

Fig. 12.5 A pair of pollinia in *Pergularia*. Each pollinium is enclosing numerous pollen grains. (*After M. R. Vijayaraghavan and A. K. Shukla*, 1976, *Annals of Botany, Vol.* 40.)

Very recently, it has been shown that the type of fossil pollen present in an area may be helpful in petroleum exploration.

Ovary

The female gametophyte, called embryo sac, is formed within the megasporangium, the ovule (Fig. 12 6). The latter is attached either singly or in a cluster to a tissue in the ovary—the placenta The stalk of the ovule is called the *funiculus* At the time of fertilization, the ovule generally comprises a massive nucellar tissue enveloped almost completely by one or more integuments leaving a small opening at one end, called the *micropyle.* This is the main passage for the entry of a pollen tube into the ovule The basal region of the ovule, where the funiculus is attached, is called the *chalaza.* The embryo sac is situated in the nucellus.

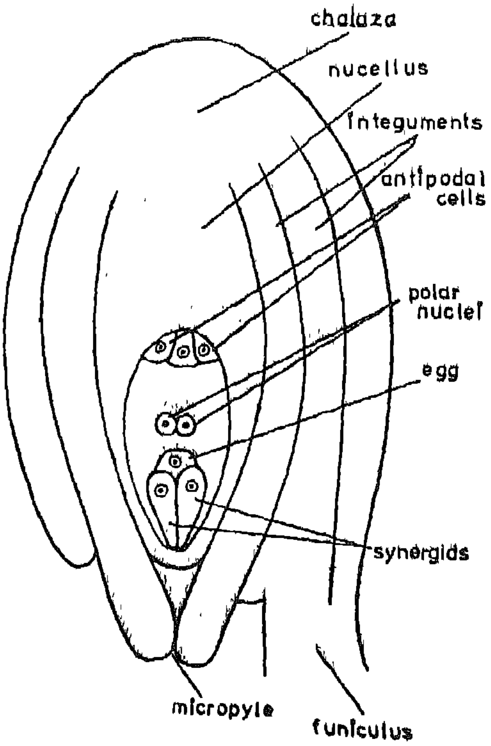


Fig. 12.6 Diagram to show the various parts of a fully formed ovule.

A hypodermal cell in the nucellus enlarges and becomes modified into the primary archegonial cell. This divides to form a primary parietal cell and a primary sporogenous cell. The former may divide further to form a variable number of wall layers or may remain undivided. The primary sporogenous cell functions as the megaspore mother cell and undergoes meiosis to form a tetrad of megaspores, which is usually linear. Three of the four megaspores degenerate and the functional one, which usually lies towards the chalaza, enlarges. Its nucleus divides thrice to form eight nuclei, which arrange themselves into three groups (Fig. 12.6). The three nuclei at the micropylar pole organize into the egg apparatus which comprises two synergids and an egg cell. At the chalazal end, three nuclei organize into three antipodal cells. The remaining two nuclei eventually come together and fuse to form a diploid secondary nucleus. Thus, the mature embryo sac is a seven-celled structure. All the cells of the embryo sac are haploid, except the central cell which is diploid.

Pollination

Upon maturity, the anther dehisces to liberate the pollen grains. For effecting fertilization, pollen must reach the right stigma which would support its germination and the subsequent growth of the pollen tube. The transference of the pollen from the anther to the stigma is called *pollination.* When the pollen grains are transferred from the anther to the stigma of the same flower or another flower on the same plant, it is referred to as self-pollination. If they are transferred to the stigma of another plant of the same species or a different species, cross-pollination is said to have taken place.

Flowers are variously adapted to ensure either self – or cross-pillination. As you

would appreciate, self-pollination is possible only in monoecious plants or those bearing bisexual flowers in which sex organs attain maturity almost simultaneously. The most effective device for promoting self-pollination is cleistogamy. Flowers showing this feature do not open fully to expose the sex organs. Thus, pollen has to fall only on the stigma within the same flower. Pea-flower is a good example of this condition.

In dioecious plants such as mulberry and *bhang*, cross-pollination becomes obligatory. However, in plants with bisexual flowers various devices exist to prevent self-pollination and promote cross-pollination This is because cross-pollination provides opportunities for genetic recombination and greater variability, and the progeny are usually more healthy. Some of the adaptations that promote cross-pollination in bisexual flowers are as follows:

1. *Self-sterility:* Pollen grains are incapable of effecting fertilization even after being placed on the stigma of the same flower, as in *Petunia axillaris*.
2. *Dichogamy:* Male and female sex organs mature at different times, as in *Impatiens*.
3. *Herkogamy*. Male and female sex organs are so placed in a flower that the pollen grains from the anther are unable to reach the stigma in the same flower. This occurs in plants like carnation.
4. *Heterostyly:* Two types of flowers with respect to the length of the style and stamens are formed. Pollen from one type of flower can effectively pollinate the flower of only the other type, e g., *Solanum melongena*

Cross-pollinatoin is accomplished with the help of external agencies, such as wind (anemophily), water (hydrophily), insects (entomophily), birds (ornithophily) and bats (cheiropterophily). Plants have developed special features to facilitate dispersal of their pollen by these agencies. For example, in wind-pollinated plants pollen grains are produced in large numbers to make up for the huge wastage. Further, the pollen grains of such plants are small, light, smooth and dry. Female flowers of the wind-pollinated plants bear large, feathery or brushlike stigmas to gather air-borne pollen grains.

Among animals, insects are the chief pollinators and exhibit various types of intimate relationships with the flowers they visit. Some insects which help in pollination are bees, flies, moths, wasps, and beetles. Of these, bees are the main flower visitors The bee-pollinated flowers are generally attractive, because of their bright colours, fragrance or unusual shape. Insects (with the exception of butterflies) are blind to red colour but can see the ultra-violet. Flowers produce nectar which is stored either at the base of the corolla tube or in a special structure called the *spur*. Bees visit flowers not with the purpose of pollinating them, but to collect pollen and nectar. In this process, they bring about pollination.

Salvia shows a specialized "turn-pipe" floral mechanism for bee pollination (Fig 12 7). The flowers of *Salvia* have a bilipped corolla (Fig. 12 7A, B) and the two stamens are attached to the corolla tube. Only one-half of each anther is fertile. The sterile halves of both the anthers jointly form a plate which is placed above the lower lip, at the mouth of the flower (Fig. 12.7D). The fertile halves are well removed from the plate due to elongation of the connective. They are situated under the hood of the upper lip of the corolla. As a bee lands on the lower lip and tries to suck the nectar, it pushes against the sterile plate which automatically brings down the fertile anthers which dust the pollen on its back (Fig. 12.7B, C). In

those flowers in which the anthers have already discharged the pollen, the stigma hangs down When a pollen-laden bee visits such a flower, its back rubs against the stigma (Fig. 12.7E) and, thus, pollination is brought about.

Pollen usually has short viability. However, the conditions that can prolong its life in storage are being studied Plant scientists have developed methods of collecting pollen on a large scale and storing it for breeding plants with desirable characters even in far-off places

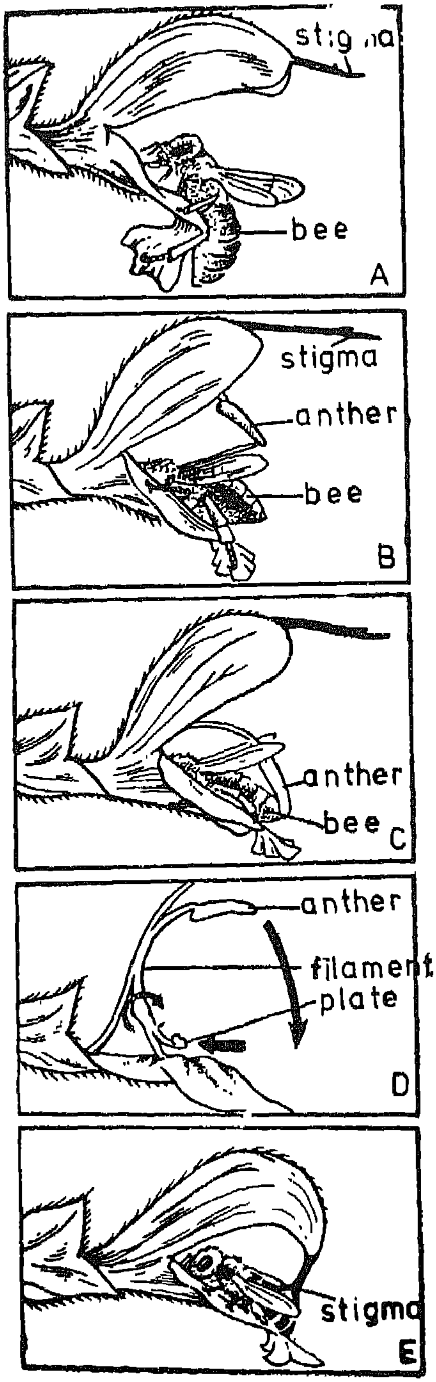


Fig. 12.7 Bee pollination in *Salvia*. *A-C*—Stages in pollen-transfer from anther to the back of the bee; *D*—The arrows indicate the mechanism involved in the deposition of pollen on the bee *E*—Transfer of pollen from the bee to the stigma. (*After S. S. Bhojwani and S. P. Bhatnagar*, 1975, *The Embryology of Angiosperms, Vikas Publishing House, Pvt. Ltd., Delhi.*)

Fertilization

After reaching the right stigma, pollen grains germinate (Fig. 12 8). A short pollen tube emerges at the germ pore; normally, only one tube is formed by a grain For the initial growth of the pollen tube, the food material stored in the pollen grains is utilized It is believed that the substances present in the secretion of the stigma may provide the necessary factors for pollen germination. Almost the entire content of the pollen grain moves into the pollen tube The vegetative nucleus usually moves to the tip of the tube, followed by the generative nucleus or the two male gametes, if they have already been formed. The elongation of the pollen tube is restricted largely to the tip region. The final length achieved by the pollen tube depends on the length of the style. For example, in the beet plant it is only a few mm long; in the maize plant it may exceed 450 mm

Based on the internal structure, styles are classified into two main types.

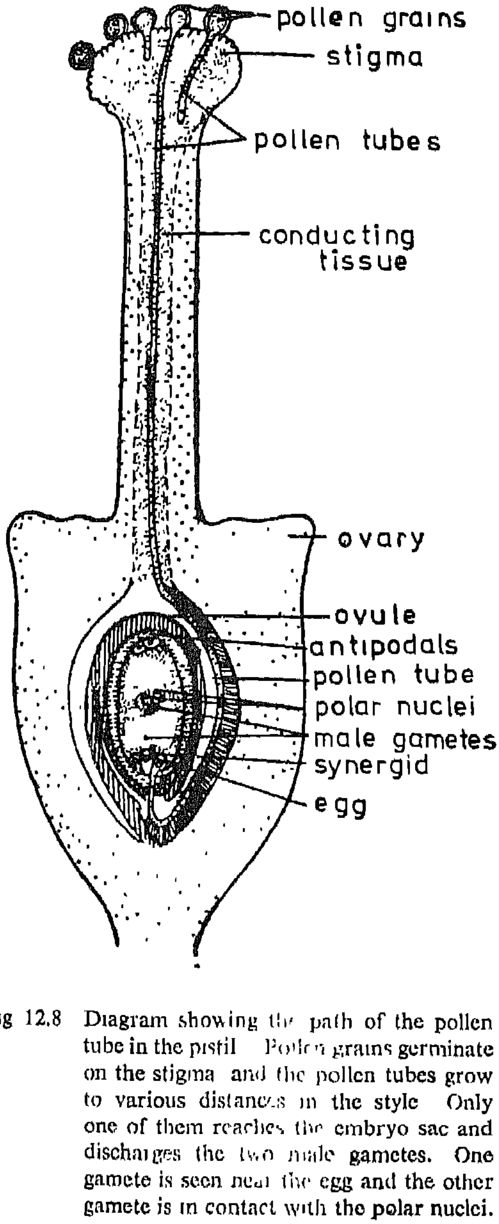


Fig 12.8 Diagram showing the path of the pollen tube in the pistil Pollen grains germinate on the stigma and the pollen tubes grow to various distances in the style Only one of them reaches the embryo sac and discharges the two male gametes. One gamete is seen near the egg and the other gamete is in contact with the polar nuclei.

(a) *Hollow style*, with a wide stylar canal lined by large canal cells, and (b) *Solid style*, which has a conducting tissue made up of cells with thick, pectin-containing walls. In plants with the hollow style, the pollen tube grows on the surface of the canal cells, whereas in the solid style the pollen tube grows through the walls of the cells of the conducting tissue without entering the cells. The pollen tube gets into the ovule generally through the micropyle (Fig. 12.8), passes across the nucellus and enters the embryo sac. It finds its way into one of the synergids and not the egg or the central cell of the embryo sac The contents of the pollen tube are discharged into the synergid. The nucleus of one of the male gametes migrates into the egg and fuses with its nucleus This process is called *syngamy* The nucleus of the other male gamete moves into the central cell and unites with the polar nuclei or the secondary nucleus (triple fusion). The fusion product of syngamy is termed zygote. The product of triple fusion is the primary endosperm nucleus This act in which two elements of the embryo sac are fertilized at one time by two male gametes is described as double-fertilization

Seed Development

After fertilization, the style, stamens, and petals wither away. The calyx is also shed, but in some plants, such as brinjal, tomato and gooseberry, it persists even in the mature fruit It is biologically important that pollination and fertilization stimulate tissues of the ovules and the ovary wall to grow actively and cause seed and fruit development, respectively. The zygote develops into the embryo, the primary endosperm nucleus forms the endosperm tissue, the integuments are transformed into the seed coat(s), while the ovary wall gives rise to the fruit tissue

The early development of the embryo is marked by a regular pattern of divisions which is fairly constant for species under normal conditions. The events leading to the formation of a mature embryo constitute embryogeny (Fig. 12.9 A-G). A full-grown embryo has an embryonal axis with

shoot tip or plumule at one end and root tip or radicle at the other end Attached laterally to the embryonal axis are one or two cotyledons. Rarely, however, a mature

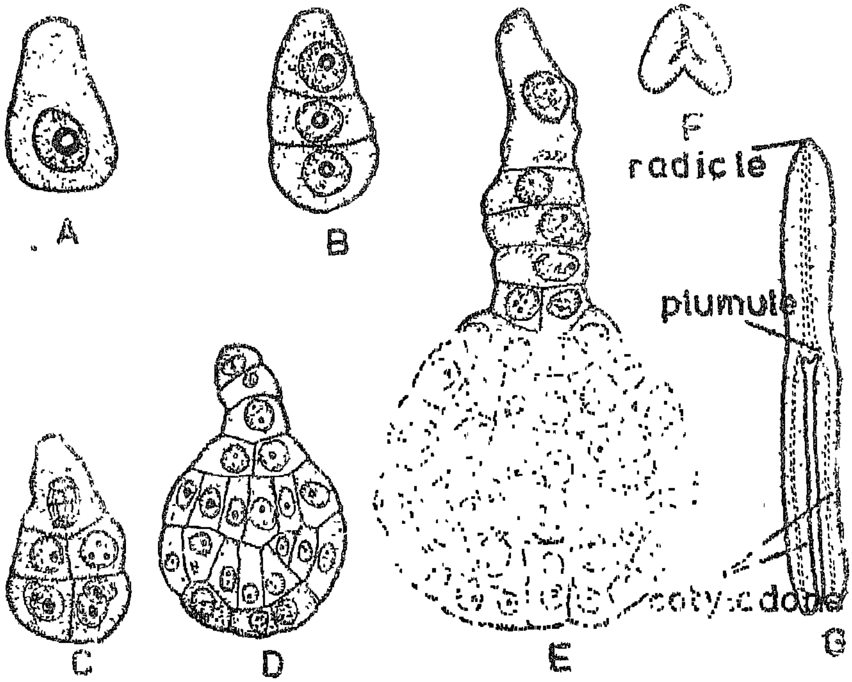


Fig. 12 9 Some stages in the embryogeny of *Erigeron bonariensis*. *A-E* are sectional views highly enlarged to show cellular details, and *F*, *G* are whole mounts in low magnifications. *A*—Zygote, *B-D*—Early stages *E*—Globular embryo; *E*—Heart shaped embryo, *G*—Mature, dicotyledonous embryo. (*After Sehgal*, 1966.)

embryo is merely a spherical structure lacking the rudiments of plumule, radicle or cotyledons (orchids, *Utricularia*, *Orobanche*).

Even before the division of the zygote, the primary endosperm nucleus starts dividing. The development of endosperm is mainly of two types: (1) Cellular (Fig. 12.10 A-E), in which the first division of the primary endosperm nucleus and all subsequent divisions of its derivatives are accompanied by cell wall formation, e.g., *Datura*, *Petunia*, and (2) Nuclear (Fig 12.11 A-C), in which the division of the primary endosperm nucleus and a few subsequent nuclear divisions are not accompanied by wall formation This results in a condition where the central cell of the embryo sac has a few to several thousand free nuclei suspended in its sap. Eventually, however, wall formation sets in and the endosperm becomes cellular. In the coconut, cell wall formation in the endosperm is never complete; the mature fruit contains both cellular (meat) and the free nuclear (water) endosperm. In a few palms like areca (*Areca*), date (*Phoenix* and vegetable ivory (*Phytelephas microcarpa*); the endosperm becomes extremely hard.

Fig. 12.11 Three stages in the development of nuclear endosperm in *Acalypha indica*. *A*-*B*—Free nuclear stages; *C*—A later stage when the endosperm has become cellular. (*After Johri and Kapil*, 1953.)

EXERCISES

1 Discuss the effects of a certain type of air-borne pollen on human health
2. What is double-fertilization ? What is its significance ?
3. In what sense is the nature of the wall of the microspore tetrad different from that of ordinary (somatic) cells ?
4 Pollen grains are usually shed individually. What term is used when all the pollen of an anther locule is shed as one unit? Name a plant where this condition is observed
5. Write a concise account of endosperm development.
6. Explain the fate of the following in a mature fruit :
(a) integuments, (b) ovary wall, (c) egg, and (4) secondary nucleus
7 With the help of diagrams, compare the structure of male and female gametophytes in an angiosperm
8. How would you explain seed-set in papaya in the absence of a male plant in close vicinity of a female plant ?
9. Suppose the haploid number of chromosomes in a flowering plant is 12 What will be the ploidy in the cells of integuments, nucellus, antipodals, endosperm and embryo of that plant ?
10 Compare the male gametophyte of pine with that of an angiosperm.

CHAPTER 13

Fruit

IT IS not easy to define fruit. Botanically, a mature ovary may be termed a true fruit. However, other floral parts may also take part in fruit formation. When this happens, the fruit is called a false fruit. For example, in apple the main edible portion of the fruit is the fleshy receptacle (Fig. 13.1) This is also true of strawberries and figs.

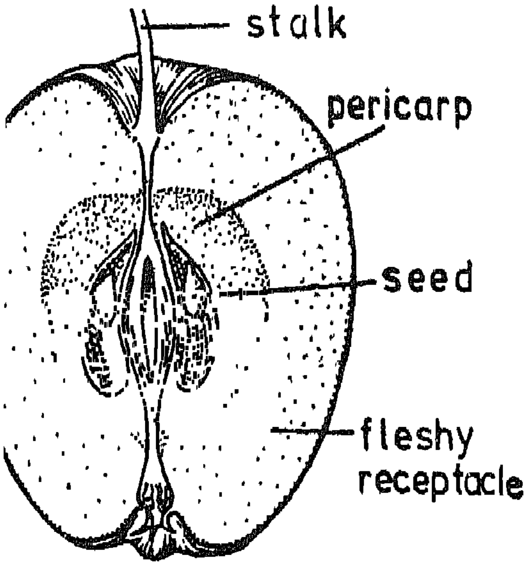
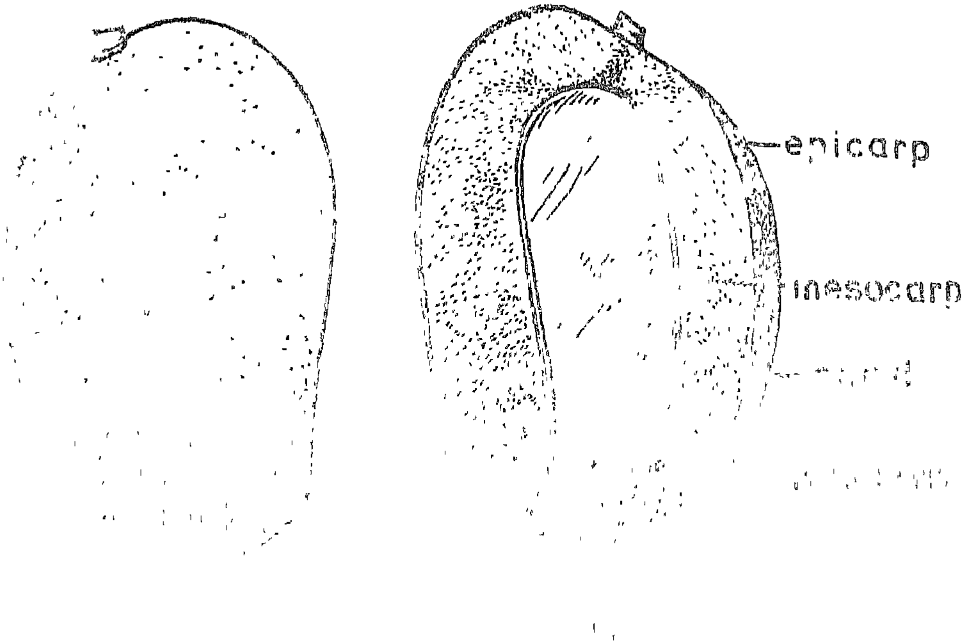


Fig. 13 1 Vertical section of an apple. The edible portion of the fruit is the massive receptacle which encloses the cartilaginous portion derived from the ovary.

The wall of a true fruit, pericarp, is divisible into three zones. In the ripe mango (Fig. 13.2), the outer, thin and leathery part, which is usually discarded, is the epicarp. The sweet fleshy part that is eaten constitutes the mesocarp, and the innermost hard zone that encloses the seed is the endocarp. The nature of these three zones varies in different fruits. In dry fruits, the pericarp is papery or woody and is not easily distinguishable into the three zones.

Development

During flower development, the ovary is the last organ to differentiate At the stage of flower opening (anthesis), the sepals, petals, and stamens are mature but the ovary is only partially developed. Pollination stimulates it to grow. Strictly speaking, post-pollination development of the ovary is fruit development. Pollination contributes to fruit development in the following ways: (1) it is essential for fertilization and, consequently, for seed development, (2) it prevents ovary abscission (Fig. 13.3), and (3) it stimulates the growth of the ovary It has been demonstrated that pollen contains small amounts of auxin which together with a limited



[illegible]

[illegible] can support [illegible] subsequent [illegible] development [illegible] which [illegible] known to synthesise [illegible] Thus, seeds [illegible] key role in fruit development. [illegible] apple, the areas showing poor development lack seeds. The experiment with strawberries by Nitsch is very illuminating in this context (Fig. [illegible]A-D) [illegible] aggregate fruit, the edible part is the fleshy receptacle, and the small seeds (individual fruits) are arranged on its surface. If in a young strawberry (within [illegible] days after pollination) all the carpels are removed, the receptacle does not grow at all. If only a few carpels are retained here and there on the receptacle, the fleshy tissue will develop only around them. By selectively removing some [illegible] fruit development could also be [illegible] by [illegible] pollination [illegible] carpels (unpollinated carpels do not form seeds, [illegible]) However, normal fruit development could be supported even after removing the carpels or completely avoiding pollination [illegible] applying small amounts of auxin.

In the development of a fruit both cell division and cell expansion are involved. The growth of the ovary after fertilization may be rapid. For example, the pumpkin ovary shows a 20-fold increase in about two weeks' time.

All the flowers borne on a plant do not always mature into fruits. In mango, for example, fruit-set is extremely low as compared to the total number of flowers produced. Shedding of flowers may occur

Fig. 11.3 [illegible] ovaries. [illegible] 1947, [illegible]

before or after anthesis [illegible] may drop. Dropping of [illegible] young fruits is of advantage to the cultivator because it results in the production of fruits of larger size. In [illegible] orchard trees, such as apples, pears and [illegible], flowers thinning by hormonal spray is a regular practice.

Fruit Ripening

As soon as the growth of the ovary wall due to cell division and cell enlargement stops, the fruit is said to be mature. This is followed by the final phase of fruit [illegible] period, the conversion of starch into [illegible] the reduction in the concentration [illegible] the production of various [illegible] the breakdown of chlorophyll lead to changes in colour, texture, taste, and flavour of the fruit. A mature fruit of mango is hard and green and its edible portion white and sour. On ripening, the mesocarp becomes yellow orange, juicy and sweet. A characteristic feature of ripening of some fruits (like banana) is a sudden increase in respiration which is known as the climacteric. After this stage, the

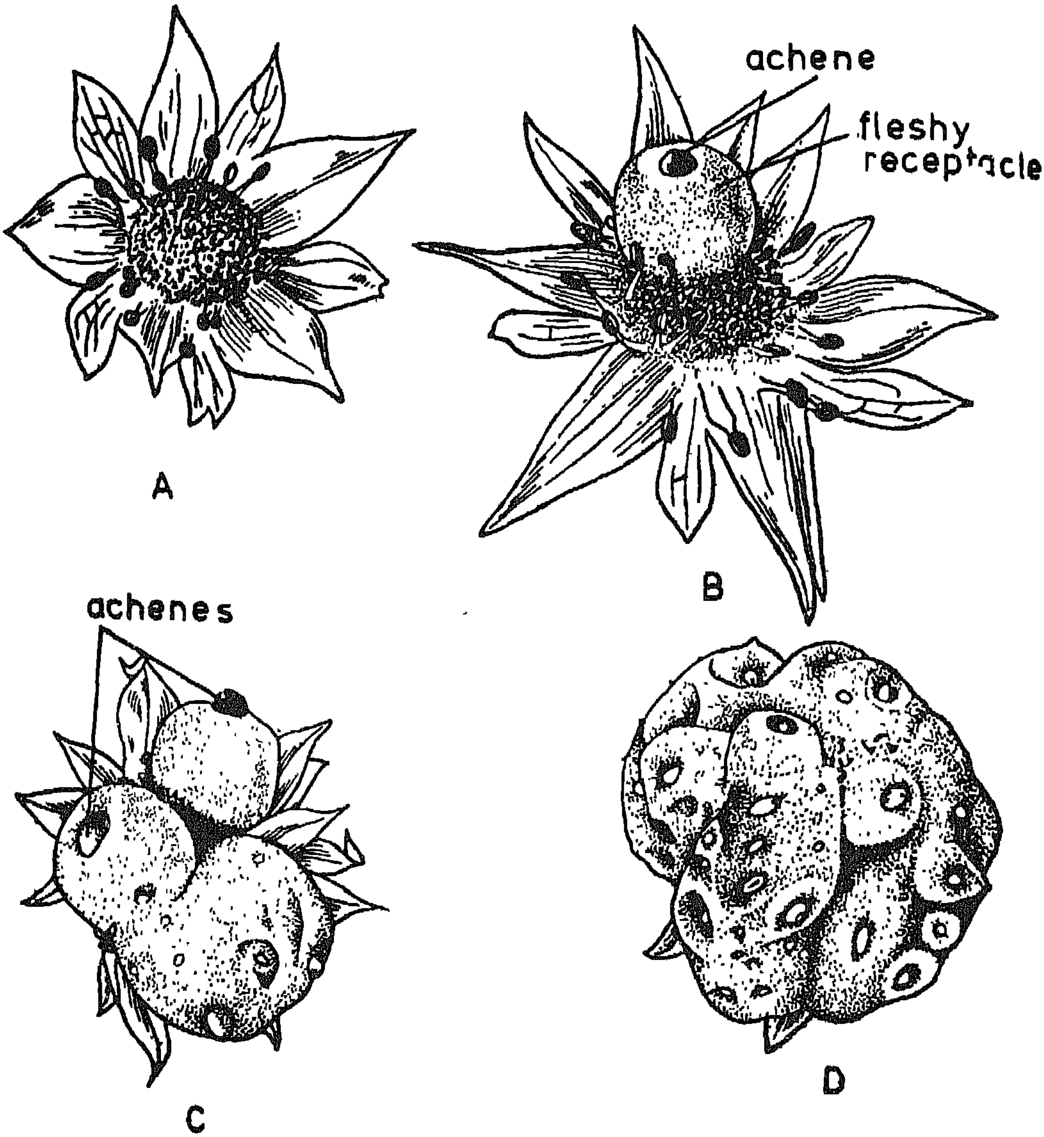


Fig. 13.4 An experiment performed by Nitsch to demonstrate the profound effect of developing seeds on the growth of the strawberry fruit. In this plant the succulent part of the fruit is derived from the receptacle, and the single-seeded true fruits (achenes) are embedded on its surface. Seed development can be supressed by avoiding pollination. *A*—Unpollinated flower: the receptacle has not developed at all; *B*—Only one carpel was pollinated: the receptacle has grown only around the pollinated carpel; *C*— Several seeds and correspondingly several areas of receptacular growth are seen; *D*—The number of seeds developed is higher than that in *C* the receptacle is approaching the shape of abnormal strawberry fruit. (*From J. P. Nitsch*, 1952, *Quarterly Review of Biology*, *Vol.* 27.)

fruit starts decaying. Although from the point of view of the fruit, ripening leads to death, for man and other animals it is a stage which is most useful

Parthenocrapy

Some plants are able to form fruits without fertilization. Such fruits are called parthenocarpic and the phenomenon is known as parthenocarpy. Parthenocarpic fruits are either seeedless or contain empty or non-viable seeds. In these fruits, the "seed-factor" for fruit growth is provided by the tissue of the ovary wall itself. Seedless varieties of grapes and oranges have been reported to have up to seven times as much auxin in the ovaries of unpollinated flowers as seeded varieties. This may explain the normal development of parthenocarpic fruits even in the absence of healthy seeds. Most commonly cultivated varieties of banana are parthenocarpic Parthenocarpic oranges and watermelons are also very common. Even in those plants which normally bear seeded fruits, parthenocarpy could be induced by the application of low concentrations of auxin or gibberellin

Parthenocarpy is of great commercial value. Parthenocarpic fruits are ideal for consumption as such, or in the preparation of jams and fruit juices on a commercial scale. You can imagine the annoyance caused by seeds while eating a watermelon or guava

Biological Significance of Fruit Formation

Fruits (of all categories) were used by the ancient man as his main food, and even today they form an important part of man's diet. However, we might ask the question: "why does a plant invest so much of its food in the production of fruit?" Certainly, not for human consumption. The fruit serves the plant in various ways. It protects the immature seeds against hostile climatic conditions and animals. The seeds remain enclosed in the fruit until they are ready to germinate or, at least, withstand the possible unfavourable environmental conditions. The function of seed-protection by the fruit wall is also achieved through its colour. When young, most fruits are green, and remain hidden in the green foliage. As the seeds mature, the fruit acquires bright colours and attract the seed-dispersing agents. Immature fruits also offer chemical defence against the animals as they often contain such unpalatable and repelling substances as astringents, tannins, bitter alkaloids and sour acids which disappear upon ripening

Another important role played by the fruit tissues is in the dispersal of seeds to distant localities which is of great biological significance.

EXERCISES

1. Give a botanical definition of the term 'fruit', and explain how it differs from the common man's point of view.
2. Draw a sectional view of the mango fruit and label the various parts.
3. What is the significance of pollination in fruit development?

4. Write a concise account in your own language of Nitsch's experiment on the role of seeds in fruit development
5. Taking a green banana or mango as an example, enumerate the various changes that occur during ripening.
6. Name ten fruits available in your market and list the morphological nature of the edible part(s) in each case
7. In what ways does a fruit serve the plant?
8. Explain the following terms: (a) parthenocarpy, (b) premature fruit drop, and (c) false fruit.

CHAPTER 14

Asexual Reproduction

NORMAL sexual reproduction involves two major processes: (a) meiosis, by which diploid sporophytic cells give rise to haploid gametes and (b) fertilization, which reconstitutes the sporophytic diploid generation through gametic fusion. Some plants are able to multiply by asexual means which do not involve either of these processes. Asexual reproduction, also called apomixis, is essentially of two types:

1. Agamospermy: In this category, the seed is retained as the unit of propagation, but it is formed without sexual union.
2. Vegetative reproduction. In this mode of asexual reproduction, the vegetative parts of the plant body such as rhizome, runner, tubers, and bulbs are used as propagules.

Agamospermy: In agamospermy, the embryo sac is diploid because it is formed without meiosis. Such embryo sacs may develop from megaspore mother cells (diplospory) or from any other cell of the nucellus (apospory). The diploid egg in these embryo sacs develops into an embryo, without fusing with the male gamete. This process is called *parthenogenesis*. For parthenogenesis, however, the stimulus of pollination is essential.

Another type of agamospermy is adventive embryony in which the embryos arise directly from the cells of the nucellus or the integuments. Adventive embryony usually leads to the formation of more than one embryo per seed. In certain species of *Citrus*, seeds may contain 2-40 embryos, of which only one will be the sexual embryo. As in parthenogenesis pollination, stimulus appears to be essential for the initiation and development of adventive embryos.

Vegetative Reproduction: When a portion of the plant body becomes detached and develops into an independent individual, we say that vegetative reproduction has occurred. The simplest kind of vegetative reproduction is shown by unicellular organisms such as bacteria, yeast and diatoms. In these organisms, the cell divides into two, and each one grows into an adult cell after separation. In certain filamentous algae like *Spirogyra*, a mechanical injury or the death of certain cells results in the breaking up of the filament into two or more portions, each of which is capable of growing into an independent individual. In liverworts, the death or decay of the older regions of the thallus up to the point of dichotomy leads to the separation of two lobes, and each grows into an adult form. Vegetative multiplication is fairly common in flowering plants

The mint plant spreads on the soil surface by the active growth of its runner (horizontal stem) in all directions. The runner strikes roots, and bears leafy branches at the nodes (Fig. 14.1). The plant can be propagated vegetatively by planting a cutting of the stem

Fig. 14.1 A runner of the mint plant bearing numerous adventitious roots and a shoot at each node.

The prolific capacity for vegetative multiplication in the fleshy leaves of *Bryophyllum* can be demonstrated in a classroom. Detach a healthy leaf from the plant, and place it horizontally on the surface of moist soil, or moist filter paper. In a few days, you will see plantlets arising from the notches along the margin of the leaf (Fig. 14.2). You can even take a portion from the margin of the leaf with a single notch and place it on a moist surface and obtain a new plant. In *Bryophyllum*, shoot meristems are already present in the leaf notches but these usually remain dormant in intact plants. When the leaves are detached, dormancy of the buds is released and with the availability of moisture they are able to grow into new plants. In *Bryophyllum daigremontianum*, however, plantlets develop along the margins of intact, healthy leaves.

It is not essential to have preformed buds for vegetative multiplication When a stem or a root cutting is provided with appropriate growth conditions, it may differentiate, adventitious buds and roots and establish a new plant. Similarly, small pieces of the tissue excised from any part of the plant body are capable of giving rise to numerous new plants in aseptic cultures. The various types of vegetative propagation are as follows:

1 *Utilization of specialized vegetative structures*—Certain plants bear specialized structures, such as tubers (root of sweet potato, tuberous stem of potato), corm (gladiolus), rhizome (ginger), bulb (onion), bulbils, runners and offsets which help the pl nt to survive adverse conditions and propagate vegetatively. These structures have also been used by man for vegetative multiplication of these plants

   As a commercial practice, potato crop is raised by tubers and not by seeds. Selected potato tubers are taken and planted as such or cut into small pieces such that each piece has at least one 'eye'. The latter has at least three buds. The propagules are able to give rise to new plants, complete with roots and shoots (Fig 14 3) Similarly, sweet potato is commonly propagated through its tuberous roots

2 *Cuttings*—It refers to regeneration of roots and shoots, and formation of a complete plant from the detached plant parts. Cuttings may be taken from the stem, root, or leaf. Sugarcane, coffee, tea, cocoa, citrus, bougainvillea, rose and many other horticultural plants are largely propagated through stem cuttings.

3. *Layering*—In this method, an intact branch of a plant is bent down close to the soil, and the portion below the shoot tip is covered with moist soil in

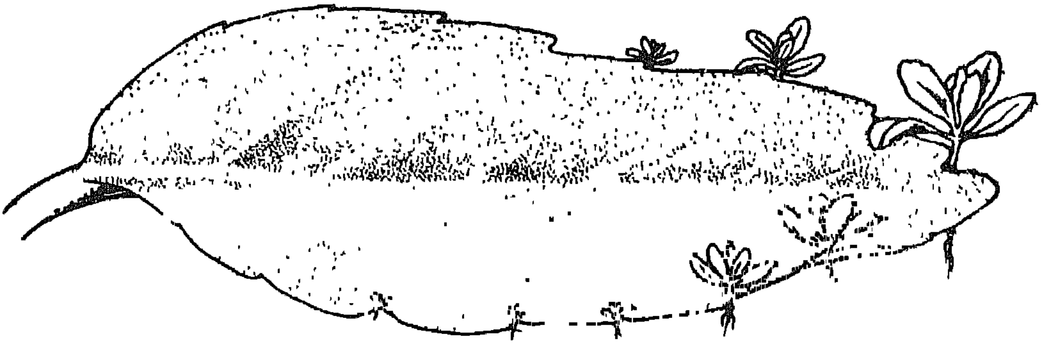


Fig 14.2 Buds present in individual notches along the margin of a *Bryophyllum* leaf are capable of forming new plants

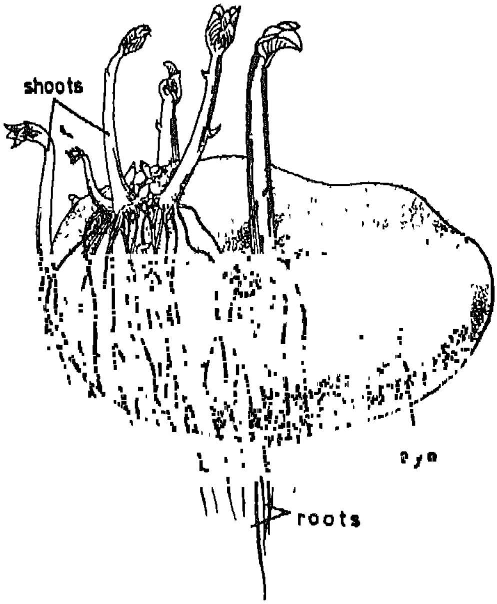


Fig. 14.3 A sprouted potato tuber showing the development of many plants

such a way that the growing tip of the stem remains above the soil surface (Fig. 14.4). In a few weeks, when the covered portion of the stem has developed a reasonable root system it is clipped off from the parent plant and grown as an independent individual. This is commonly practised with jasmine, strawberry and black-raspberry.

Air-layering is another practice in which from a portion of a branch the bark is removed, and it is covered with moist moss and enclosed in a polythene bag. When roots appear, the stem is cut below the level of roots and planted.

4. *Grafting*.—This is an established practice in which the ultimate plant is derived from two different individuals — the root of one (stock) and the shoot of the other (scion). The former is qualitatively poor but resistant to diseases and efficient in absorbing water and minerals. The scion is the stem cutting from a superior plant. Usually, the grafting ends of stock and scion are cut obliquely (Fig. 14.5A) and placed face-to-face (Fig. 14.5B) in such a way that the cambia of the two are in intimate contact. The two are bound firmly with tape (Fig. 14.5C), rubber or even nails, until their tissues unite and a vascular continuity is established. Grafting has been found extremely useful in raising rubber, citrus, mangoes, apples, roses, etc.

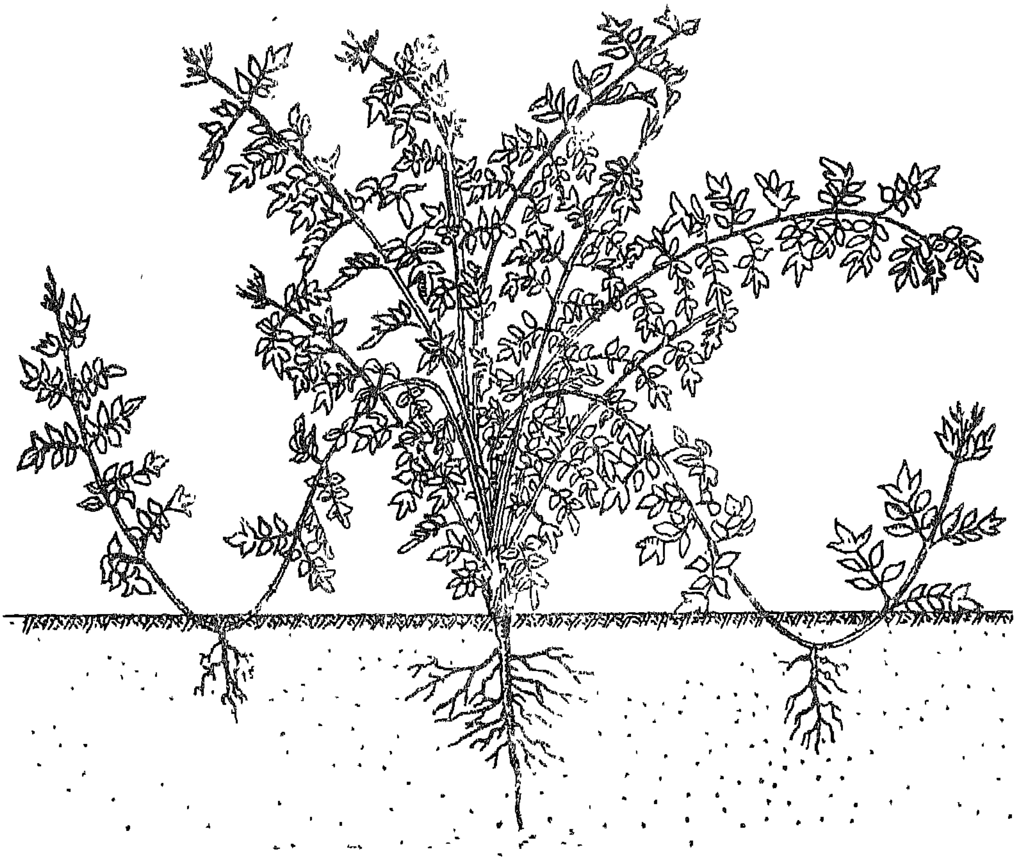


Fig. 14.4 Layering — a common method of propagating ornamental plants. Two branches of the jasmine plant are seen striking roots in the soil. The rooted branches will develop into new individuals when detached from the parent plant.

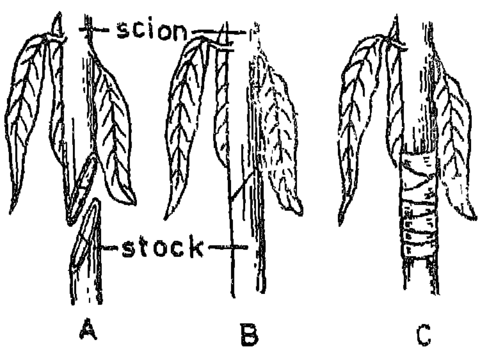


Fig. 14.5 Grafting in mango. The lower end of the scion and the upper end of the stock are cut obliquely (*A*) and brought together (*B*). A tape is then tied around the graft (*C*).

5. *Micropropagation*—In this method, the technique of plant cell, tissue and organ culture is utilized (you will learn details of this technique later). A small piece of tissue is excised from a plant and is transferred to a container with a nutrient medium under aseptic conditions The tissue proliferates into a fast-growing unorganized mass called the callus. This callus can be maintained and multiplied for an unlimited period. Small portions of the tissue are transferred to another medium, which induces the differentiation of plantlets. The plantlets can be

transplanted in pots or soil and raised to maturity By this method an indefinite number of plants can be obtained, starting from a small amount of parental tissue (Fig 14 6). Some of the plants in which micropropagation has been used with great advantage are orchids, carnations, freesias, chrysanthemums, and asparagus

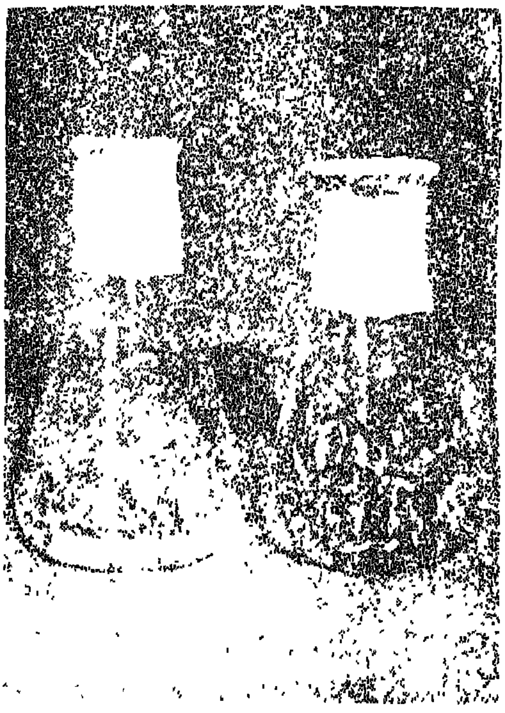


Fig. 14 6 Flasks containing hundreds of *Dendrobium* plants produced through micropropagation. (*Courtesy Professor Thavron Vajrubhaya, Department of Botany, Chulalongkorn University, Bangkok.*)

Usually, tissues of the shoot apex are virus-free even if the remaining parts of the plant are infested with it. By excising the shoot apices (containing a few tiny leaves) from the infected plants and growing them on a nutrient medium, it is possible to recover virus-free plants. This technique has been helpful in obtaining virus-free potatoes, tulips, sugarcane, etc.

Significance of vegetative propagation .

1. Plants raised through vegetative propagation from a single plant constitute a genetically uniform population, called the *clone*. On the other hand, plants derived from seeds may show variations due to genetic recombination and segregation. Thus, by propagating plants through vegetative means a large stock of selected strains can be built up and maintained without loosing the desirable characters
2. It is the only means of reproduction and perpetuation for species which never form viable seeds, such as bananas figs, pineapple, seedless grapes, seedless oranges, roses, chrysanthemums, and jasmine.
3. It is a more rapid, easier and cheaper method of propagating plants with long periods of seed dormancy or juvenile phase.

EXERCISES

1 Seeds of many *Citrus* species contain more than one embryo. What are such seeds called? How are the additional embryos formed?
2. Enumerate the merits and demerits of vegetative propagation in plants.

3. If you are asked to multiply a selected variety of seedless fruit plant, what procedure(s) would you adopt?
4. If a branch of *dasehri* mango is grafted on a tree producing *desi* mangoes, what type of mangoes will be borne on the grafted branch and other branches of the plant?
5. Write brief notes on the following (a) cutting, (b) layering, (c) micropropagation, (d) apospory, (e) diplospory, and (f) parthenogenesis.

CHAPTER 15

Plant Tissue and Organ Culture

EVEN THE most highly evolved flowering plant is built on a much simpler plan as compared to an animal. For example, plants do not have an elaborate nervous system, a circulatory system, a lymph system or sense organs. A mature plant is made up of millions of cells which are ultimately derived from a zygote. These cells are held together with the help of middle lamellae and have their primary and/or secondary walls They communicate with the adjacent cells through plasmodesmatal connections. You have learnt that some of the plant cells in the leaf are able to photosynthesise, whereas others perform the function of transport, and still others act as spore mother cells The fate of a cell seems to depend on its location in the plant. One of the most challenging problems in developmental biology is to explain how the derivatives of the zygote become so diverse in their structure and function. What is intriguing is whether cell differentiation in a plant body is achieved through a permanent change in the genetic make-up, or results from a modification in the expression potential of the otherwise uniform cells.

One of the scientific methods of solving a complicated problem is to study the components separately and to understand the relationship between the parts and the whole. In essence, the technique of plant tissue culture involves the isolation of cells, tissues, or organs from the plant body and growing them aseptically, in suitable containers, on an artificial nutrient medium, under controlled environmental conditions.

Technique

Most of the cultured tissues cannot synthesise their own food and need an external supply. When cultured, even green tissues loose their chlorophyll gradually and become heterotrophic. For their sustained growth, therefore, the cultured tissues require sugars and vitamins, in addition to mineral salts. Furthermore, on a medium containing the above substances (basal medium) only some tissues, such as the crown gall tissues, are able to grow Others require one or more plant growth regulators or complex substances like coconut milk as supplements to the basal medium.

The same medium suited to grow plant tissues would also support luxuriant growth of microorganisms, such as bacteria and fungi. If they happen to reach the medium somehow, they multiply, overgrow the plant tissue and finally kill it. It is, therefore, extremely important to maintain completely

aseptic conditions inside the culture vessels. Sterilization of the medium is achieved by autoclaving at 120°C for 15 minutes. The plant parts to be cultured and the instruments used should also be suitably sterilized. The chamber used for culturing the tissues is kept dust-free. UV-radiation is generally used for killing the microbes in this chamber.

Gottlieb Haberlandt (1902), a well known German botanist, is credited with the idea of growing isolated leaf cells. Unluckily for him, the attempts were unsuscessful. Twenty years later, Robbins and Kotte, working independently, obtained partial success in growing isolated roots In 1932, White established root cultures of tomato which could be maintained in an active state of growth for over 30 years by periodic transfer of the apical portion of the root to a fresh medium (subculture). This work demonstrated that the excised roots needed an exogenous supply of B vitamins as they are incapable of synthesizing these.

Organs with intact meristems may continue to grow in culture in organized fashion. Thus, a shoot segment with an intact apex may develop into a full plant with adventitious roots. Pollinated ovaries have also been grown into mature fruits in test-tubes. However, the fully differentiated tissues excised from the mesophyll, pith, endosperm or secondary phloem usually show an altogether different pattern of growth. Their cells divide in irregular fashion forming an unorganized and undifferentiated mass of tissue called the callus. Success in raising callus cultures from isolated plant parts over an indefinite period of time was first achieved by Gautheret, Nobecourt, and White, simultaneously, in 1939. With greater knowledge of the nutritional requirements of cultured tissues and the discovery of a large number of growth-promoting substances, it has now become possible to raise continuously growing cultures from most plant tissues, including those which would have never divided in nature.

Depending on the nature of the plant tissue cultured, the callus may remain as an unorganized mass or may show the differentiation of shoots, roots or embryolike structures (embryoids). Where normally no organ formation occurs, treatment with hormones can cause their induction. One of the important discoveries in tissue culture research by Skoog and Miller was the role played by auxin and cytokinin in the control of shoot and root formation (Fig 15.1).

Commonly, numerous independent shoot buds and roots differentiate from a single callus. The shoot buds may establish a vascular connection with the roots formed at another site in the same callus. Or, when the buds are transferred to a fresh medium they form adventitious roots and develop into whole plants By understanding the factors which can stimulate the formation of organs or whole plants in specific tissues it is possible to apply this technique for micropropagation (for details, see chapter on Asexual Reproduction).

Steward and his co-workers made an important finding with carrot cultures (Fig. 15.2). They grew small pieces of mature carrot roots in a liquid medium supplemented with coconut milk, in special containers By gently shaking the cultures, cells and cell clusters became free and floated into the medium. Some of them developed into rooting clumps When these were transferred to the tubes containing a semi-solid medium, they gave rise to whole plants that flowered and set seeds. Thus, it was demonstrated that even mature cells, when freed from the plant body, had the ability to reorganize new individuals. This capacity was termed *cellular totipotency*.

The real test of cellular totipotency required the demonstration of a plant being formed from a single cell in total isolation. In general, isolated single cells do not grow. Muir and co-workers (1958) were successful

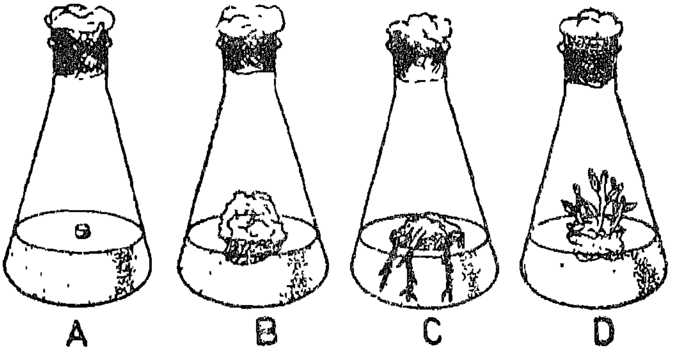


Fig. 15.1 An experiment to demonstrate the effect of growth regulators (auxins and cytokinin) on growth and differentiation in plant tissue cultures. *A*—On the nutrient medium lacking a growth regulator the tobacco pith tissue showed very poor growth, *B*—In the presence of a cytokinin (0.2mg of kinetin in a litre of medium) a vigorously growing callus was formed, *C*—When transferred to a medium containing 3mg/l of indoleacetic acid (an auxin) and 0 2mg/l of kinetin (a cytokinin) this callus differentiated only roots, *D*—If a portion of the same callus was planted on a medium with higher concentration of kinetin (1mg/l) and lower concentration of indoleacetic acid (0.03mg/l), it differentiated only shoots (*Adapted from F C Skoog et al*, 1963, ***Phytochemistry*, *Vol* 6,** *and J P. Helgeson et al*, 1969, *Plant Physiology*, *Vol.* 44)

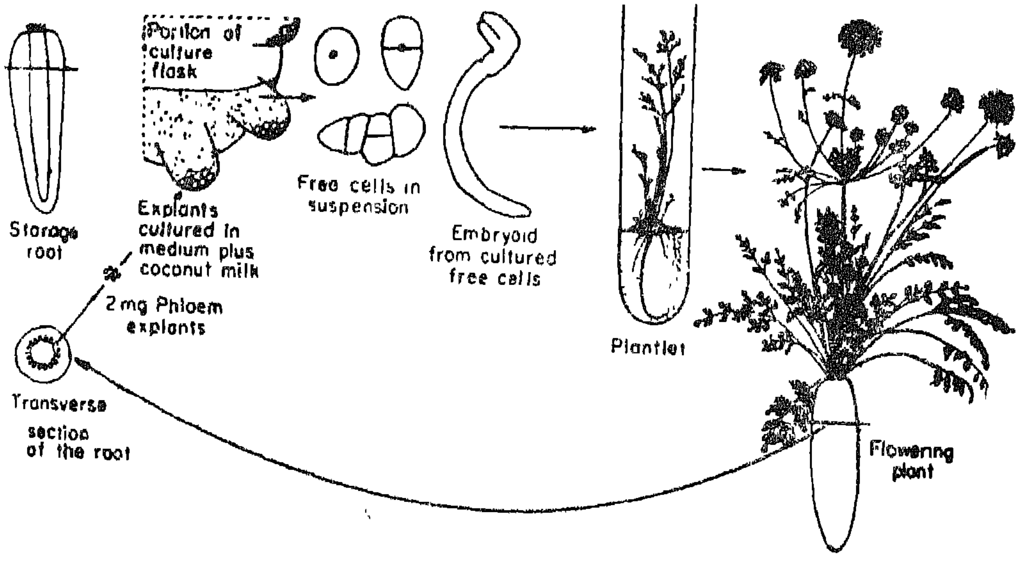


Fig. 15.2 An experiment conducted by Steward to demonstrate the totipotency of plant cells. Slices of the carrot root (shown on the left) were cut and small pieces of tissues were taken from the phloem region. These were inoculated into a liquid medium in special flasks, which were rotated slowly. The tissue grew actively and single cells and small cell aggregates dissociated into the medium (a single cell and some cell aggregates are drawn near the flask). Some of the cell clumps developed roots, and, when transferred to a semi-solid medium, these rooted nodules formed shoots (shown inside the tube). These plants could be transferred to soil where they developed into flowering plants. Phloem tissues taken from the roots of these plants could be used to repeat the cycle. (*Adapted from F. C. Steward et al.*, 1964, ***Science*, *Vol.* 143.**)

in growing small amounts of tissue from single cells of tobacco, using the nurse technique (Fig. 15.3). They placed a single cell on a piece of filter paper which rested

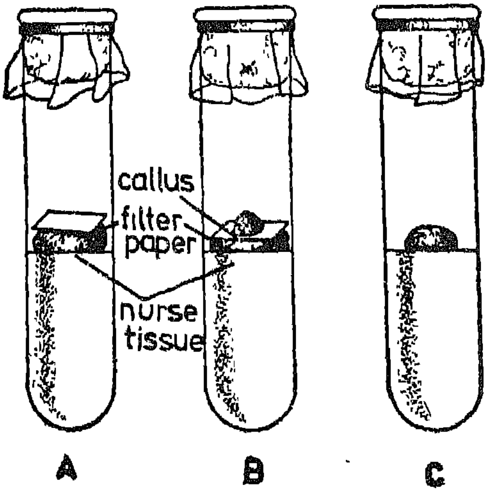


Fig. 15.3 Nurse-tissue technique first used by Muir to raise single-cell clones. *A*—A single cell from the callus is placed on filter paper lying on the top of a large callus (nurse tissue); *B*—The cell divides and forms a small tissue; *C*—This tissue is transferred from the filter paper to the medium directly where it is able to grow further. (*After W. H Muir et al.*, 1958, *American Journal of Botany*, *Vol.* 45.)

on an actively growing callus of tobacco. In this way, the cell was physically separated from the callus but was able to obtain the necessary factor/s for division from the callus which acted as the nurse tissue. Subsequently, Vasil and Hildebrandt (1965) were able to raise whole plants of tobacco by first growing isolated single cells into masses of tissue in micro-chambers and later transferring them to flasks (Fig. 15.4A-J).

Todate, single cell clones of carrot, tobacco and several other plants (also callus masses derived from different tissues) are known to differentiate whole plants in culture. On the basis of this evidence it may be inferred that, at least theoretically, every living plant cell, irrespective of its age and location, is totipotent. Nevertheless, the zygote is a unique cell in the sense that its mode of development has not been duplicated by most cultured cells. While the zygote directly gives rise to a bipolar embryo through a series of divisions in a predetermined fashion, the isolated single cells of tobacco divide quite irregularly to form a mass from which roots and shoot buds differentiate eventually.

Steward and his co-workers demonstrated that in carrot the callus raised from immature embryos is able to differentiate embryoids identical to the zygotic embryo of this plant. If the callus is transferred from a semi-solid medium to a liquid medium and shaken continuously, it breaks down into single cells. When shaking is stopped, numerous embryoids appear. Interestingly, stages resembling globular, heart-shaped, and torpedo-shaped embryos can be seen in the cultures, suggesting that the embryoids were formed through the regular stages of embryogeny. According to Steward's estimate, from one carrot embryo nearly 100,000 embryoids can be obtained, each of which can grow into a flowering plant and set viable seeds. Differentiation of embryoids from cultured tissues is now known in several plants, of which buttercup (*Ranunculus*) is specially noteworthy. Konar and Nataraja (1965) have shown that a callus raised from any part of this plant differentiates embryoids (Fig. 15.5A,B). Interestingly, these can develop even from the intact epidermal cells of the hypocotyl of plantlets (Fig. 15.5C,D).

A convincing demonstration of the single-cell origin of embryoids was given by Guha and Maheshwari (1966). They reported that in the cultured anthers of *Datura* numerous embryoids developed. A detailed examination showed that these embryoids originated from the pollen grains (Fig. 15.6 A-I). Subsequently, pollen embryoids have

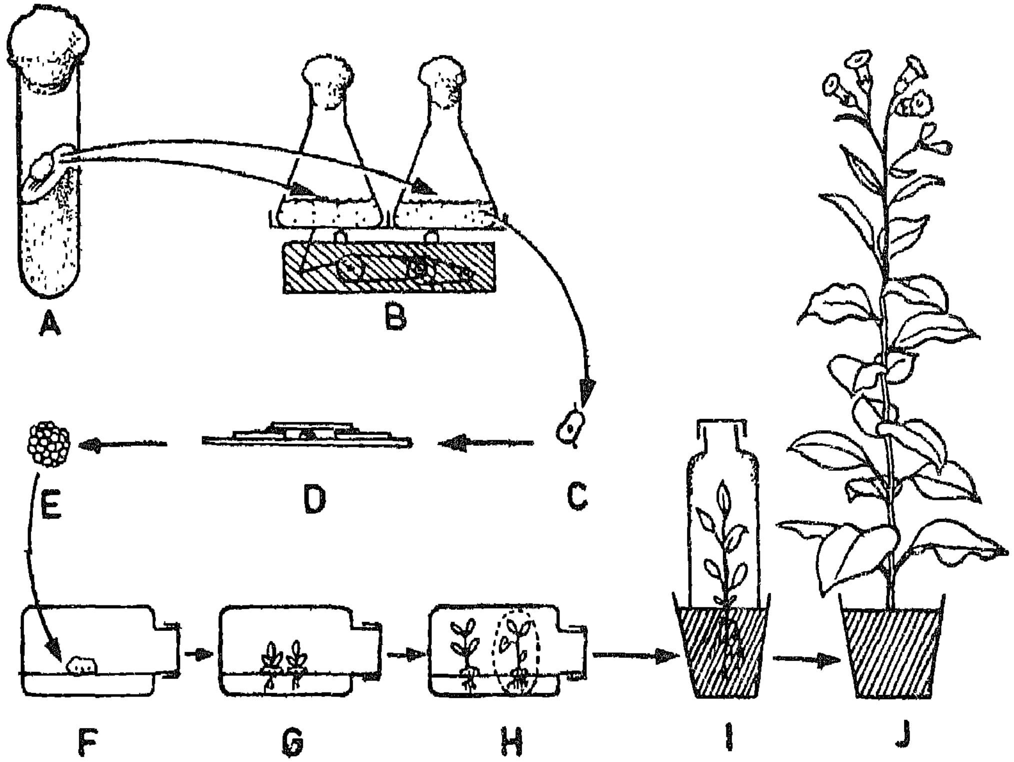


Fig. 15.4 Development of tobacco plants from single cells. A callus is raised from a small piece of tissue excised from the pith (*A*). By transferring it to a liquid medium and shaking the culture flasks (*B*), the callus is dissociated into a single cell (*C*), is mechanically removed from the flask, and is placed on a slide in a drop of culture medium (*D*). A microchamber is formed around the culture drop using the three-cover slips (*D*). A small tissue (*E*) derived from the cell through repeated divisions is then transferred to a semi-solid medium where it grows into a large callus (*E*) and, eventually, differentiates plants (*F*, *G*). When transferred to soil (*H*), these plants grow to maturity, flower and set seeds (*I*). (*After R. N. Konar* 1966, *and adapted from the work of V. Vasil and A C. Hildebrandt*, 1965, *Science*, *Vol.* 150).

been reported from several other plants (wheat, rice, tomato, asparagus). Remarkable progress in this area has been made by Nitsch and her associates in France. They prepared a purely synthetic medium on which isolated single-celled pollen grains directly developed into embryoids. The latter formed haploid plants. The value of haploid plants lies in the fact that they contain only one-half the genome of the parent plant. They are sexually sterile. However, by treatment with colchicine, diploid homozygous plants can be obtained. You have already learnt about the production of hybrids in plants like maize by crossing two homozygous lines. Natural haploids are rare and are obtained only by accident. Anther and pollen culture, therefore, are the speedier methods of haploid production.

There are numerous applications of tissue culture but only a few will be listed here :

1. Rapid multiplication of desirable and

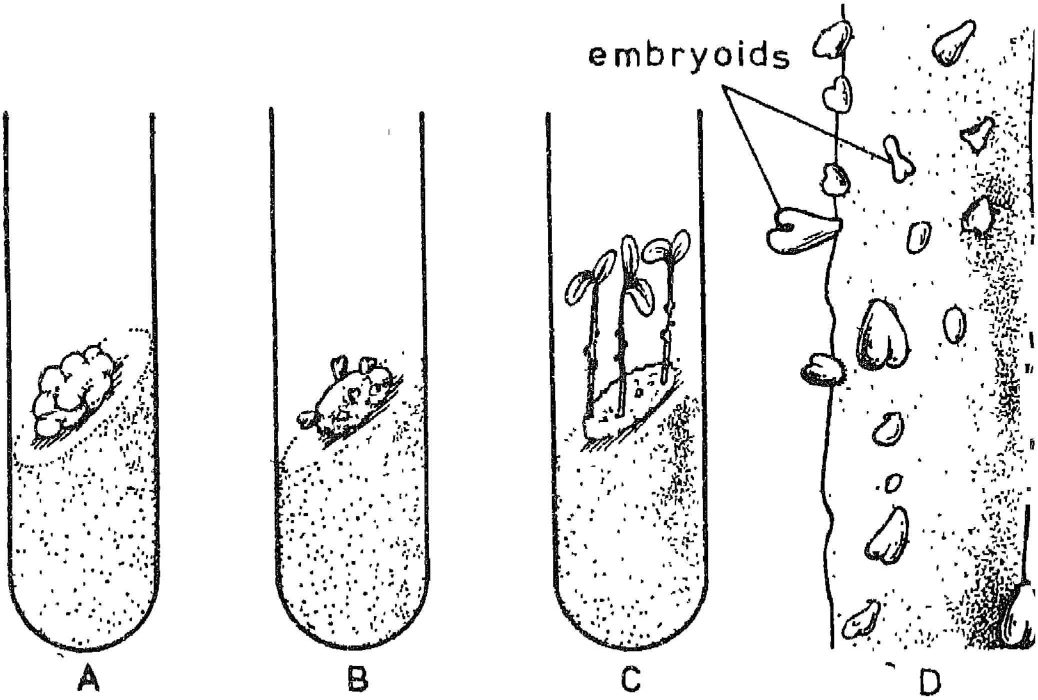


Fig. 15.5

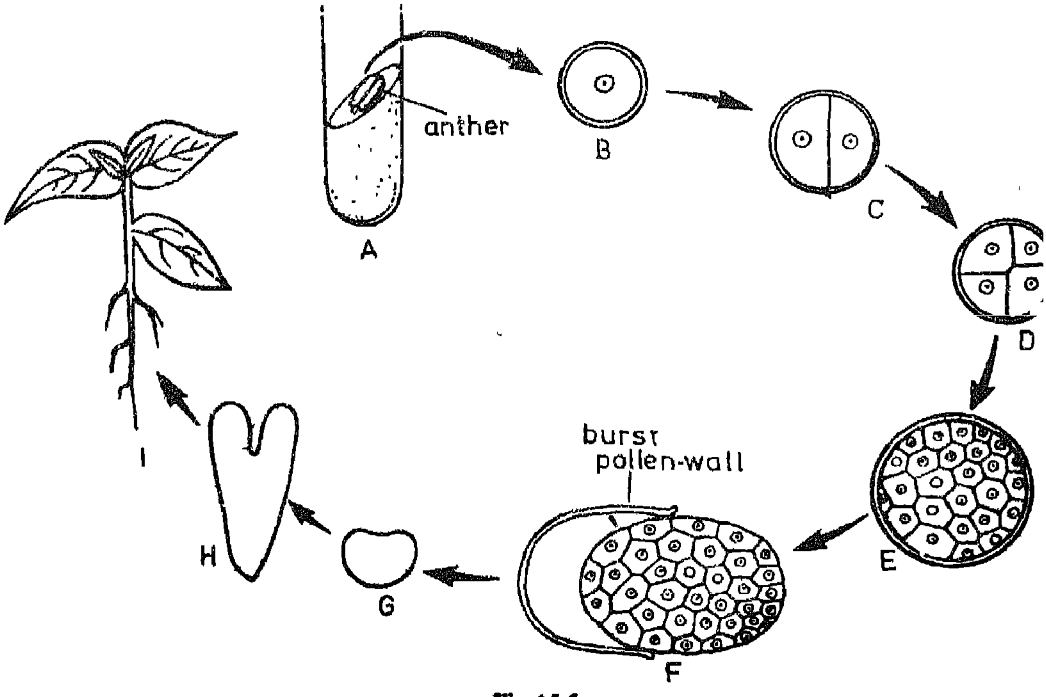
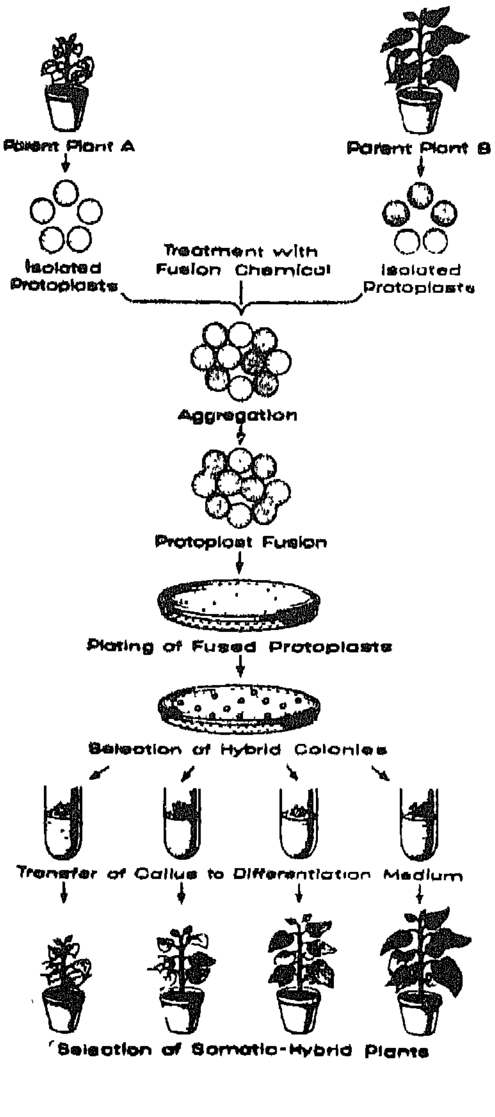


Fig. 15·6

Fig 15.5 Embryoid formation in tissue cultures of butter cup. *A*—An unorganized callus, *B*—six-week old ← culture showing numerous embryoids arising from the callus, *C*—The embryoids have developed into plantlets, and a fresh crop of embryoids is seen arising from the surface of the hypocotyle donary region of these plants; *D*—The embryoid-bearing portion enlarged from Fig C. (*After R N. Konar and K Nataraja*, 1965, *Phytomorphology, Vol* 15.)

Fig 15.6 Diagram showing the development of haploid plants from the pollen grains of tobacco The anther ← of the right stage is excised from the flower bud and cultured on a suitable medium (*A*) Some of the pollen inside the anther undergoes repeated divisions (*B-D*), forming a multicellular tissue within the parent wall (*E*). Eventually, the pollen wall bursts, releasing the tissue mass (*F*) which directly develops into an embryoid and germinates to form a haploid plant

rare plants (see chapter on Asexual Reproduction).



2 Recovering healthy stocks from virus infected plants through shoot-tip culture (see chapter on Asexual Reproduction)

3. Embryo culture This technique has been useful not only in overcoming seed dormancy but also in producing viable plants from crosses which normally fail due to the death of immature embryos (jute, rice)

4 Production of a large number of haploids and homozygous diploids.

5 Somatic hybridization (Fig. 15.7). You might have learnt about the fusion of the cells of man and mouse Fusion proved difficult in plant cells because of their adherence by the pectin-rich matrix and the presence of rigid cellulose walls

Fig 15.7 Diagrammatic representation of the steps ← involved in somatic hybridization. Leaf pieces of the two parents (plant *A* with non-green leaves and plant *B* with deep-green leaves) are separately treated with a mixture of enzymes to obtain spherical protoplasts. When protoplasts of the two populations are mixed and treated with polythylene glycol, they first adhere to each other in groups of two or more and later fuse. These fusion bodies are then cultured on a suitable medium wherein their nuclei fuse, and the hybrid cells thus formed divide to give rise to callus masses. These calli are transferred to another medium which induces plantlet formation. From amongst these plants hybrids are selected. (*After Y. P. S. Bajaj*, 1977, *Fundamental and Applied Aspects of Plant Tissue Culture, Springer Verlag, Germany*)

By using commercial enzymes such as cellulase and pectinase it is now possible to dissociate plant tissues into single cells and remove their walls. The resulting naked cells, called protoplasts, behave like animal cells. When plant protoplasts from different species are brought in contact with each other in the presence of a substance like polythylene glycol (PEG), they readily fuse. The fusion product of protoplasts from two different plants is called a *heterokaryon.* On a suitable medium the heterokaryon synthesises a new wall, and its nuclei fuse to establish a true hybrid cell. If this hybrid cell undergoes repeated divisions and forms a callus, differentiation of hybrid plants can be anticipated. Using this approach, interspecific somatic hybrids have been produced in tobacco and petunia. This technique of protoplast fusion and culture holds great promise for synthesising rare hybrids which cannot otherwise be produced sexually because of incompatibility.

Abnormal Growths

When a dicotyledonous plant is injured by a sharp blade, the cells surrounding the cut divide to form a tissue mass and begin to heal the wound. The activation of permanent cells during wound-healing is brought about by certain chemical substances hypothetically called the "wound hormone".

The association of certain microorganisms with the wound-healing tissue leads to an altogether different growth pattern. Cell divisions become irregular and a tissue with the ability for unlimited growth is formed. Such tissues are called *tumours.* Some of the causative factors of tumours are bacteria, viruses, insects or fungi, and hybridization. The most well-investigated tumours are those caused by the bacterium *Agrobacterium tumefaciens.* These tumours are called crown galls because they can sometimes attain the size of a human head. The bacterium releases a tumour-inducing principle (TIP) which alters the normal tissue to undergo irregular divisions. Gradually, the tumour tissue acquires the ability to grow even in the absence of the bacterium. Secondary tumours which appear at a distance from the primary tumour lack the bacterium but grow as actively as the primary tumour. Tumour tissues have a higher concentration of growth substances, especially auxin, as compared to the normal tissues of the same plant. Because of this feature isolated tumour tissues can grow for an unlimited period on a simple medium Sensitivity of plants to tumour-inducing agents may vary considerably.

An actively growing crown gall tissue may give the impression that its cells are permanently altered, but this is not so In some plants with a high degree of regeneration ability (*Nicotiana*, *Kalanchoe*), moderately virulant strains of the bacterium (such as Walnut T37 strain) induce tumours which have abnormal shootlike structures. Such partially organized tumours are called *teratoma.* By isolating abnormal shoots from the teratoma and grafting them on to a decapitated normal plants repeatedly, it is possible to recover normal flowering shoots.

In some species, tumours arise spontaneously without a causative organism. Such tumours have a genetic basis and commonly occur in certain hybrids of genera like *Nicotiana*, *Lilium* and *Lycopersicon.*

Another kind of abnormal growth is the "witches broom" caused by viruses, mycoplasma, bacteria, fungi and parasitic angiosperms. The most common example of this condition is found in mango where the entire inflorescense becomes modified into dense clusters of small, highly branched, fleshy shoots with short internodes and reduced leaves. The loss caused by witches

broom for mango growers in north India is enormous.

All abnormal growths are not irregular. Galls produced on plants by insects can be so highly organized and shapely that they may be mistaken for fruits. Common examples of insect galls are those formed on the leaves of *Ficus*, *Pongamia* and Oak.

EXERCISES

1. Briefly describe the technique of plant cell, tissue and organ culture as applied to a flowering plant.
2. List the major applications of the tissue culture technique.
3. What do you understand by this statement, "plant cells are totipotent"?
4. What essential steps are involved in plant cell fusion?
5. Imagine that you are given two unlabelled culture tubes—one containing a crown gall tissue and the other containing a callus from a normal plant. How would you identify one from the other?
6. Outline a procedure for culturing single cells of flowering plants.
7. Write explanatory notes on: (a) wound hormone, (b) somatic hybridization, (c) embryoids, and (d) witches broom.

UNIT 2

DEVELOPMENTAL BIOLOGY

Animals

Developmental Biology: Definition, Scope and History

REPRODUCTION is one of the most important characteristics of all living things. However what is initially produced in the act of reproduction is never an individual exactly resembling the parent or parents in form, size, structure and function from the very beginning. *Amoeba* reproduces by simply dividing into two smaller daughter amoebae which then must grow to full size before themselves reproducing by further division. In *Hydra*, the bud undergoes many changes to form an individual which looks like a *Hydra*. In sexually reproducing organisms, the union of a male and a female gamete produces a single cell which, after many changes gives rise to the offspring structurally and functionally resembling the parents. The entire series of events and progressive changes which gradually transform a fertilised egg, a bud or a fragment of the parent's body into a completely formed organism is termed *development*.

Embryology and Developmental Biology

Developmental events are seen most dramatically in the life history of the higher, sexually reproducing metazoans. The entire life history of these animals is clearly divisible into two distinct periods, (i) *embryonic or pre-natal period* which is passed within the egg or the womb of the mother, and (ii) *post-embryonic or post-natal* period which extends from hatching or birth up to death.

The changes and events occurring from fertilization of the egg through formation of the embryo up to hatching or birth belong to the pre-natal or embryonic period and the study of these processes is called *embryology*. The entire development of an individual beginning with its origin from a fertilised egg to its complete formation is called its *ontogeny* or *ontogenetic development*. However, development does not end at birth but continues during the post-natal period also. At haching or birth, the young animal is not only small in size but is also imperfectly developed in many respects, both structurally and physiologically. During subsequent days, weeks, months, or years, depending upon the species, many changes of progressive nature

occur as a result of which the young one becomes a mature adult, itself capable of reproduction. After the adult reaches the peak, a series of other kinds of developmental changes, this time degenerative in nature, set in which ultimately lead to its death.

Developmental biology is defined as that field of biology which deals with the study of processes by which organisms undergo progressive and orderly changes in structure as well as physiology during their entire life history.

History of Embryology

The earliest records indicating man's interest in understanding and explaining reproduction and development belong to Egyptian civilization and are as old as 3000-1500 B.C. They mention speculations about the formation and growth of embryos and give prescriptions for abortion and prevention of pregnancy, etc There are sacred books of the Hindus of about 600 B.C which distinguished three ways of origin of new individuals from eggs, from living beings and from germs The *Susruta Samhita*, a monumental Indian work of the second or third century A.D, describes the development of a human child in the mother's womb

In Greece, Hippocrates (460-377 B.C) observed the development of the hen's egg, and Empedocles (fifth century B.C) considered the germination of plants as comparable to reproduction in animals According to him, in animals embryo received some parts of the body from the father's and others from the mother's seeds. The Greek philosopher and biologist, Aristotle (384-322 B.C), is regarded as the founder of the science of embryology. He studied the embryonic development of the chick and of many other animals and wrote the famous book *De Generatione Animalium* Leeuwenhoek (1632-1723), through his own hand made microscope, discovered spermatozoa in the semen and called them *animalcules* He considered the sperms to be the seed produced by the male which developed into an embryo in the soil provided by the mother

The mammalian ovum was discovered by Karl Ernst Von Baer in 1827. Von Baer studied the embryonic development of many animals and laid the foundation of modern embryology The cellular nature of sperms and ova was established with the formulation of the cell theory by Schleiden and Schwann (1838-39).

Fig. 10.2 Karl Ernst von Baer (1792-1876)

Fertilization of the egg by the actual entry of the sperm into a frog's egg was observed for the first time by George Newport in 1854. In sea urchin eggs also the same process was observed by Fol in 1877 O Hertwig (1875) observed and described the fusion of the nuclei of the sperm and the egg in the fertilized eggs of sea urchins.

Cleavage of the frog egg had been first seen by Spallanzani, an Italian biologist, in the later part of eighteenth century It was later established as a regular pheno

menon in the developing egg of other animals by several workers during the nineteenth century. In 1817, Pander described the formation of the three primary germinal layers from which all tissues and organs were developed in the chick embryo

With these discoveries, the basic cellular elements involved in sexual reproduction and also the early steps in the formation of the embryo had been well established by the third quarter of the nineteenth century About the same time better microscopes and microtomes had been invented and methods of sectioning and staining of tissues, organs and embryos had been perfected. This enabled their microscopic examination to understand the processes and developmental events during the formation and growth of the embryos.

EXERCISES

1 Distinguish between (a) Reproduction and Development, (b) Embryology and Developmental Biology.

2 List the important discoveries during the historical growth of Embryology.

3 What do the following words signify?
(1) Embryo, (2) Ontogeny

4 Who was the first to discover the following
(1) Sperm, (2) Ovum, (3) Fertilization, (4) Parthenogenesis, (5) Cleavage, (6) Mammalian follicles

5 List the important contributions of the following scientists in the field of Developmental Biology.
(1) Aristotle, (2) von Baer, (3) Newport, (4) Spallanzani, (5) Pander

Forms of Reproduction

LIVING organisms, animals and plants reproduce in several ways. Reproduction always begins with the formation of a *reproductive unit.* This unit may be produced from one parent or may involve two parents. The unit then goes through a series of developmental changes to give rise to the body of the offspring resembling the parents. Two major forms of reproduction are recognised: (i) Asexual and (ii) Sexual

Asexual Reproduction

This form of reproduction involves only one parent. The reproductive unit may be the whole body of the parent as in unicellular animals or, as in multicellular organisms, this unit may be a single cell, a bud consisting of a small group of cells or a fragment of the body of the parent. The principal ways of asexual reproduction are *binary fission, multiple fission, budding and fragmentation* (Fig 17 1).

Binary Fission

This is a simple division of the unicellular parent organism into two smaller daughter cells of roughly equal size, each of which then grows to the size of the parent before dividing again This type of

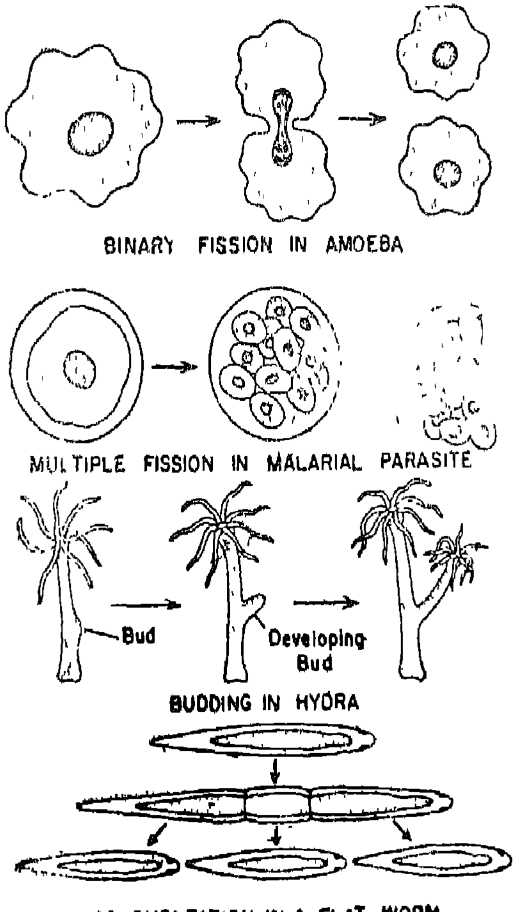


Fig. 17.1 **Forms of asexual reproduction and development in animals.**

reproduction occurs in unicellular organisms such as *Amoeba, Euglena, Paremecium*, etc.

Multiple Fission

In this kind of reproduction, first the nucleus divides a number of times but the cytoplasm remains undivided Later, cytoplasm also divides into several parts, with each part enclosing at least one nucleus. Thus, numerous daughter cells are produced from one parent cell at the same time. Multiple fission occurs in various groups of protozoa. In some of these, the process is also known as *schizogony* or *sporulation* In multiple fission, usually a cyst wall is formed before the nuclear and cytoplasmic divisions.

It should be noted that in both binary and multiple fissions the whole parent body constitutes the reproductive unit. With fission into daughter individuals, the parent body itself actually disappears.

Budding

This method of reproduction involves the formation of a reproductive unit called a bud. Each bud consists initially of a small number of cells surrounded by an epithelium. One or more such buds may be produced from a single parent body. The bud may become separated from the parent body and then may develop into a new individual; or it may separate only after the completion of development. In some cases, it may never separate and, as a result, colonies of interconnected individuals are formed. Budding is one of the common methods of reproduction in sponges, coelentrates (e.g., *Hydra)*, many tunicates (primitive chordates). Buds are also produced in some protozoans.

Fragmentation

In some animals, the body of the organism breaks up into several parts. Each part then develops into a complete organism. In some worms and certain tunicates, this process occurs spontaneously. In others, fragmentation may result from outside forces. Thus, *hydra* and planarian flat worms can be cut up into smaller fragments and from each fragment a complete individual is reconstituted

The common features in all forms of asexual reproduction are: (a) only one parent is involved, (b) all cell divisions occurring during asexual development are mitotic, and (c) the offspring are genetically identical to the parents

Sexual Reproduction

This form of reproduction, also called *gametic reproduction*, is the usual method practised by multicellular animals. The reproductive units in sexual reproduction are two kinds of highly specialized cells, the male and female gametes Each kind of gamete is ordinarily produced by a different parent and so two parents, one male and one female, participate in sexual reproduction. However, in some organisms like certain flat worms, both kinds of gametes are produced by the same individual and in their reproduction only one parent is involved.

In sexual reproduction, a male gamete fuses with a female gamete to form a single cell called *zygote* which then gives rise to the body of the offspring.

The union of two gametes also involves fusion of their nuclei into one. This introduces a ticklish problem for organisms reproducing sexually in maintaining the chromosomal number specific for animal and plant species. The number of chromosomes per cell of the body is fixed for each species. Every kind of chromosomes present in the nucleus of the cell is paired

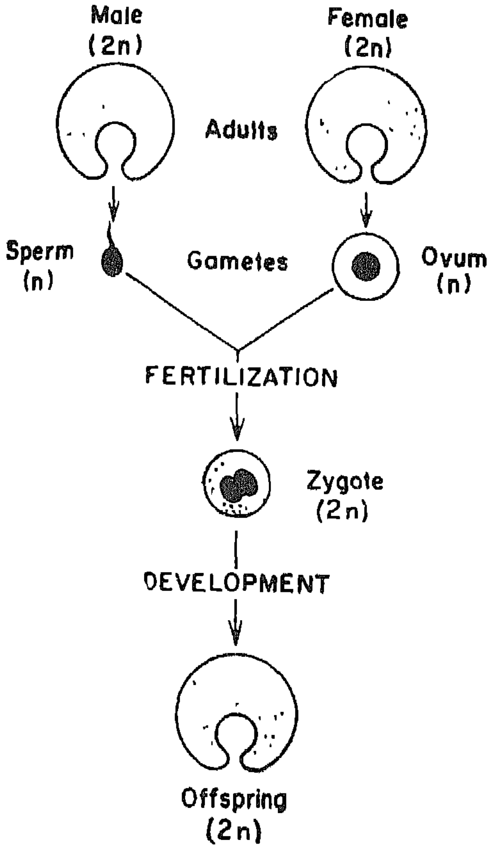


Fig. 17.2 A schematic representation of sexual (gametic) form of reproduction and development in animals.

and so there is a definite number of pairs of chromosomes in every cell of the body of each individual of the species. This number, called the diploid (2n) number, should remain constant generation after generation so that the characteristics of the species determined by these chromosomes remain unchanged (Fig. 17.2). If gametes produced by each parent were also diploid, the zygote resulting from the fusion of two such gametes will have double the number (4n) of chromosomes possessed by the parent. The gametes produced from individuals developed from such zygotes will have 4n chromosomes. In the offspring of the subsequent generation produced from zygotes resulting from the fusion of two such gametes (4n), the chromosome number will be doubled again. This process of progressive doubling of chromosomes will thus continue indefinitely through successive generations

However, in actuality the specific number of chromosomes remains constant through successive generations. This constancy is brought about by a special type of nuclear division in the reproductive cells called, *meiosis*. As a result of such a division, the daughter cells come to possess only half the number of chromosomes present in the parent cell. That is, while the parent body cell is diploid containing 2n chromosomes, each reproductive cell, i e, gamete is haploid with only 'n' chromosomes.

In all metazoan animals, with rare exceptions, meiosis occurs in the germ cells during the formation of gametes in the body of male and female parents The male as well as female gametes are all haploid. Consequently, the zygote resulting from the fusion of two such haploid gametes becomes diploid and so is the offspring that develops from this zygote.

The offspring inherit characteristics from each parent but are not genetically entirely identical with either of them. This introduces some variation in each sexually produced generation which is important from an evolutionary point of view.

The processes of development of the offspring in asexual reproduction from reproductive units such as buds or fragments is called *blastogenesis*. The development of the embryo from the zygote formed by the fusion of two gametes in sexual reproduction is known as *embryogenesis*.

EXERCISES

1. Define and distinguish between asexual and sexual forms of reproduction.
2. Enumerate the basic features of sexual reproduction
3. 'Gametic reproduction involves meiosis in order to maintain the constancy of a specific number of chromosomes through generations.' Justify this statement.
4. Explain the meaning of the following terms
   (1) Binary fission, (2) Multiple fission, (3) Budding, (4) Fragmentation (5) Blastogenesis, (6) Embryogenesis.

CHAPTER 18

Basic Features of Embryonic Development

METAZOANS are multicellular animals In size and the number of cells composing them, they range from tiny creatures, as Hydra, some worms and certain arthropods with relatively few, even countable cells, to such huge animals as an elephant made up of trilions of cells Regardless of the ultimate size of the animal, however, the embryonic development of all metazoans begins from a single cell. Further, the basic features and processes of development in all metazoans are the same. Embryogenesis in all such animals occurs through a fundamentally similar sequence of events which follow one after another to give rise to a new individual.

Phases of Embryonic Development

Gametogenesis

In all sexually reproducing organisms, the single cell or zygote which eventually gives rise to the offspring is itself formed by the fusion of two dissimilar cells—a male and a female gamete—coming from the male and female parents, respectively. These sex cells or gametes (sperms or ova) are themselves very complex and highly specialized cells very different from all other kinds of cells of the body. Originally derived from simple cells, they undergo a complicated series of developmental changes before they are ready to perform their special functions connected with the formation of a new individual. The gametes are formed in the reproductive organs or gonads of the parents and the process of their development is called *gametogenesis*. This is a collective term and includes the formation of the male gametes, sperms or spermatozoa, called *spermatogenesis*, and also that of the female gametes, ova or eggs, which are called *oogenesis* The process of gametogenesis is similar in all metazoan animals.

Fertilization

The union of a sperm and ovum, called *fertilization*, is the first phase of development during embryogenesis. Fusion of the two cells results in the production of a single cell called *zygote* which eventually gives rise to the body of the new individual.

Cleavage and Blastulation

The zygote now undergoes a series of successive and rapid mitotic divisions which transform this single cell into a multicellular body consisting of many small cells called *blastomeres*. This phase of development which immediately follows fertilization is called *cleavage* It ends with the formation of a *blastula* in which all cells are arranged on the surface over or around a cavity or the blastula which may be solid or compact

Gastrulation

The next phase of embryonic development is *gastrulation* During this phase, there occur large-scale movements and rearrangement of cells of the blastula Some of the cells remain on the surface, while others migrate inwards converting the embryo into *gastrula* which is composed now of three layers of cells called the *primary germinal layers*. The outermost layer is called the *ectoderm*, the innermost layer *endoderm* and the middle layer *mesoderm*. The details of gastrulation again differ in various animals but the ultimate result-formation of the three germinal layers is the same in all and it occurs by way of large-scale coordinated movements of the cells after the blastula stage.

Organogenesis, Morphogenesis and Differentiation

Following gastrulation, the cells of the three primary germinal layers give rise to rudiments of future tissues and organs, starting the process of *organogenesis* or organ formation. Simultaneously, the embryo gradually acquires the specific shape and form or morphology. This process is called *morphogenesis*. It is a comprehensive term and includes the development of shape and form of not merely the whole organism but also of its individual external and internal parts. Thus, we may refer to the development of the form of the eye, the nervous system, the limbs, the muscles, the bone, etc., as morphogenesis of these organs and tissues.

As the individual tissues and organs develop, the cells composing them become different from each other structurally as well as functionally as muscle cells, nerve cells, skin cells, skeletal cells, etc. Each kind of cells becomes specialized for its own distinctive functions *The process of cells originally derived from the same cell or zygote becoming different in the course of development is called differentiation.* This is a comprehensive term and is used to refer to *chemo-differentiation* (chemical differentiation of cells), *cyto-differentiation* (structural differentiation of cells), ***histo-differentiation*** or histogenesis (formation of tissues) and *organ-differentiation*, etc., according to what kind of developmental changes and at what level (cell, tissue or organ) of the organization of the embryo are being considered. The term differentiation is also often used to refer to both organogenesis and morphogenesis in the embryonic and later life

Growth

Simultaneously with the above developments, there also continuously occurs ***growth*** in the size and volume of the embryo and its parts by the increase in the number and size of the cells and in the total organic mass or protoplasm by synthesis and addition of new materials.

Gametogenesis, fertilization, cleavage, blastulation and gastrulation are discrete separate phenomena, and can be distinguished from each other. The processes of organogenesis, morphogenesis, differentiation and growth, however, occur more or less simultaneously over a long period of time during the embryonic period, and also in the larval and adult stages. Some degree

of at least chemical differentiation of cells takes place even during cleavage, blastulation and gastrulation. Morphogenesis starts with gastrulation when, due to the movements and re-arrangement of cells, a three -layered form is produced which is the beginning of the basic form or morphology of the individual

Gonads

The gametes (sperms and ova) are produced in special reproductive organs, collectively called *gonads.* The male gonads are *testes* which produce male gametes, the sperms, and the female gonads are *ovaries* which produce female gametes, ova or eggs. In most sexually reproducing animals, the males and females are separate, possessing only testes or ovaries, respectively. In a number of animals, however, both types of gonads are present in the same individual which, thus, produce sperms as well as ova. Such animals are called *hermaphrodites,* of which the common earthworm, *Pheretima posthuma,* and the common leech are familiar examples. Hermaphrodites are very rare or absent in most higher animals in which the males and females are not only separate but the two sexes can be distinguished from each other by a number of characters called the secondary sexual characters.

Gametes and Gametogenesis

Gametogenesis is an important and vital phase in the sexual reproduction of animals. The essential process during this phase is the transformation of certain cells in the gonads of parents into specialized cells—ova in the female and sperms in the male. The two types of cells must unite to form a single cell, the zygote, from which the body of the new individual is then developed. To carry out their function most effectively, therefore, the gametes should be expected to be motile so that they can meet or unite, and at the same time must be supplied with sufficient food reserves to provide energy and materials for the developing embryo The two requirements of motility and food storage cannot be met in the same cell and so this problem has been solved in nature by evolving tiny but motile sperms and large but non-motile ova filled with food reserves. This distinction into small microscopic, motile male gametes and large, non-motile female gametes is the general condition throughout the animal kingdom. This is also true of the higher mammals in which ova are relatively small and do not need to store food materials which are provided to the mother via placenta.

During the development of both sperms and ova in the testes and ovaries, respectively, there occur two meiotic divisions, also called maturation divisions, the first one of which is reductional. The daughter cells which ultimately mature as sperms or ova are, therefore, haploid. This type of cell division occurs only in the germ cells and in no other cells of the body. There are, however, some differences of the time and stage of development when these divisions occur during oogenesis and spermatogenesis.

Spermatozoa—The Male Gametes

Structure of Spermatozoa

With few exceptions, the basic structure of the sperm is the same in all animals (Fig. 18.1). A typical sperm consists of four parts: head, neck, middle piece and tail. Each part is specialized to perform a specific function. Electron microscopic studies of the past 20 years have provided

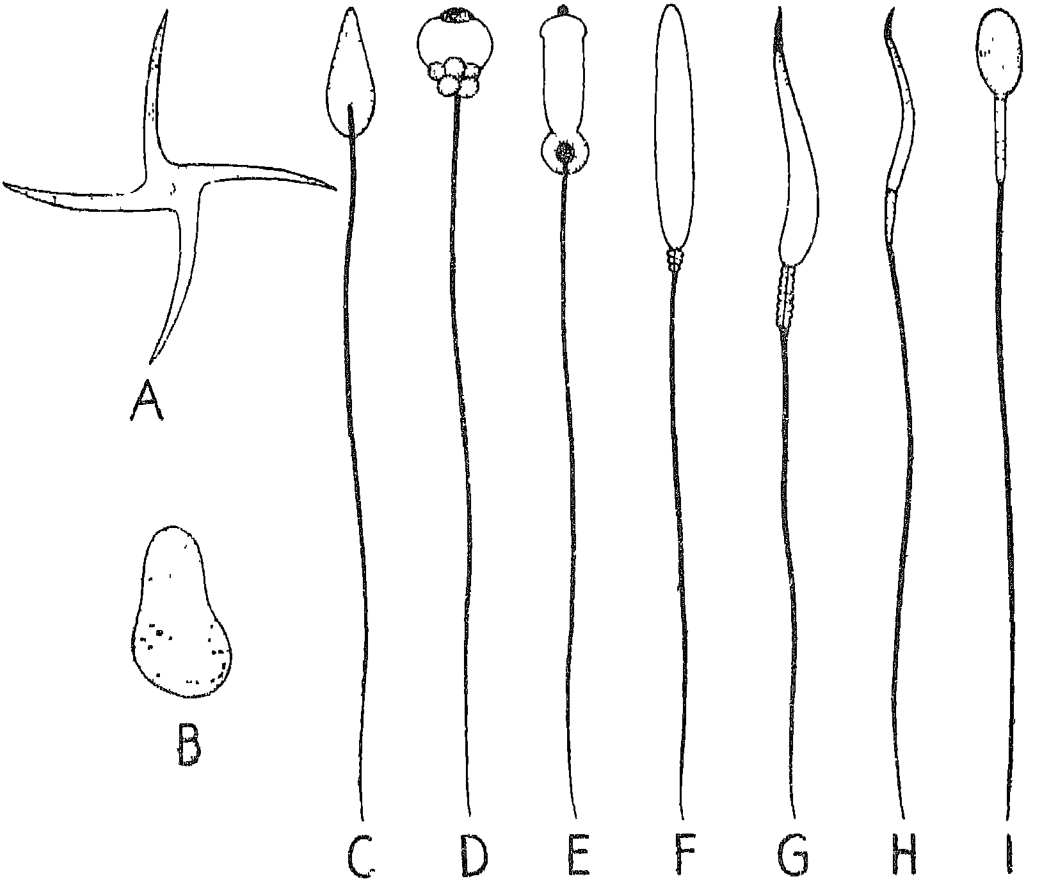


Fig. 18.1 Types of sperms in some animals: (*A*) A crayfish (Crustacea); (*B*) Ascaris (a round worm); (*C*) Sea urchin (Echinodermata); (*D*) Amphioxus, (*E*) Sturgeon (a fish); (*F*) Frog; (*G*) Turtle (Reptilia); (*H*) Chick (bird); (*I*) Man

detailed knowledge of the internal structure of each part of the sperm (Fig 18 2).

The head is composed of a large nucleus and an *acrosome* The nucleus is very compact, consisting of only concentrated DNA The acrosome is located at the tip of the head as a compact mass and possesses a double-layered membrane which extends down along the outer surface of the nucleus to form a head cap of the nucleus. The function of the acrosome is to facilitate penetration of the sperm into the ovum at fertilization. The acrosome secretes some enzymes which dissolve the egg membrane and help in the entry of the sperm into the ovum.

The neck is very short and contains two granules called the *proximal* and *distal centrioles*. The proximal centriole plays an important role in the first division of the fertilized ovum, while the distal centriole provides attachment to the axial filament of the long tail or flagellum of the sperm.

The middle piece consists entirely of a compact mass of mitochondria. They are carriers of oxidative enzymes and provide

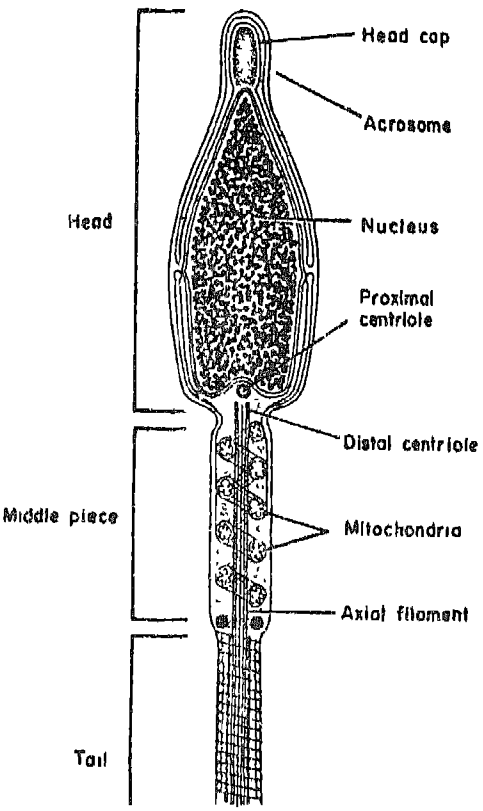


Fig. 18 2 An electron microscopic view of a mammalian sperm

energy for metabolism and movements of the sperm The middle piece is, therefore, said to be the power house of the sperm

The tail or flagellum consists of a central axial filament surrounded by a small amount of cytoplasm and an external sheath or cell membrane. The whipping, lashing or undulating motions of the tail are responsible for locomotion of the sperm Sperms require a liquid medium in which to swim to reach the ovum and often they may have to travel quite some distance to do so.

Spermatogenesis

Spermatozoa are produced in the seminiferous tubules of the testes (Fig. 18.3 & 18.4). They are derived from primordial germ cells or sperm mother cells located within the germinal epithelium lining the tubules At some time, some of the sperm mother cells become large and move inward and divide mitotically to produce daughter cells, called *spermatogonia*, which divide again to produce more of themselves Some of these spermatogonia stop dividing and enter a period of growth and are then called *primary spermatocytes* The growth is, however, not very much and the size just about double. After the growth phase, the primary spermatocyte undergoes the first meiotic or maturation division This meiotic division is reductional so that each of the two daughter cells now called *secondary spermatocytes* is haploid with 'n' number of chromosomes This first meiotic division is soon followed by the second meiotic division which, however, is equational so that the daughter cells remain haploid The four daughter cells thus derived from one primary spermatocyte as a result of two meiotic divisions are called *spermatids* and they are all haploid The spermatids do not divide and instead, each of them discards much of its water, cytoplasm and some other organelles and becomes transformed into a completely formed spermatozoan Thus from [illegible] four spermatozoa are developed The process of differentiation of spermatid into a spermatozoan is known as *spermiogenesis* (Fig 18.5) During this period of differentiation, the developing sperms have their heads embedded in the *Sertoli cells*, from which they obtain their nourishment

Spermatogenesis occurs continuously during the breeding season and also to a reduced extent in the periods between such seasons. In man and other mammals which breed throughout the year, sperm production begins at sexual maturity (about 14-16 years in boys and about three weeks after

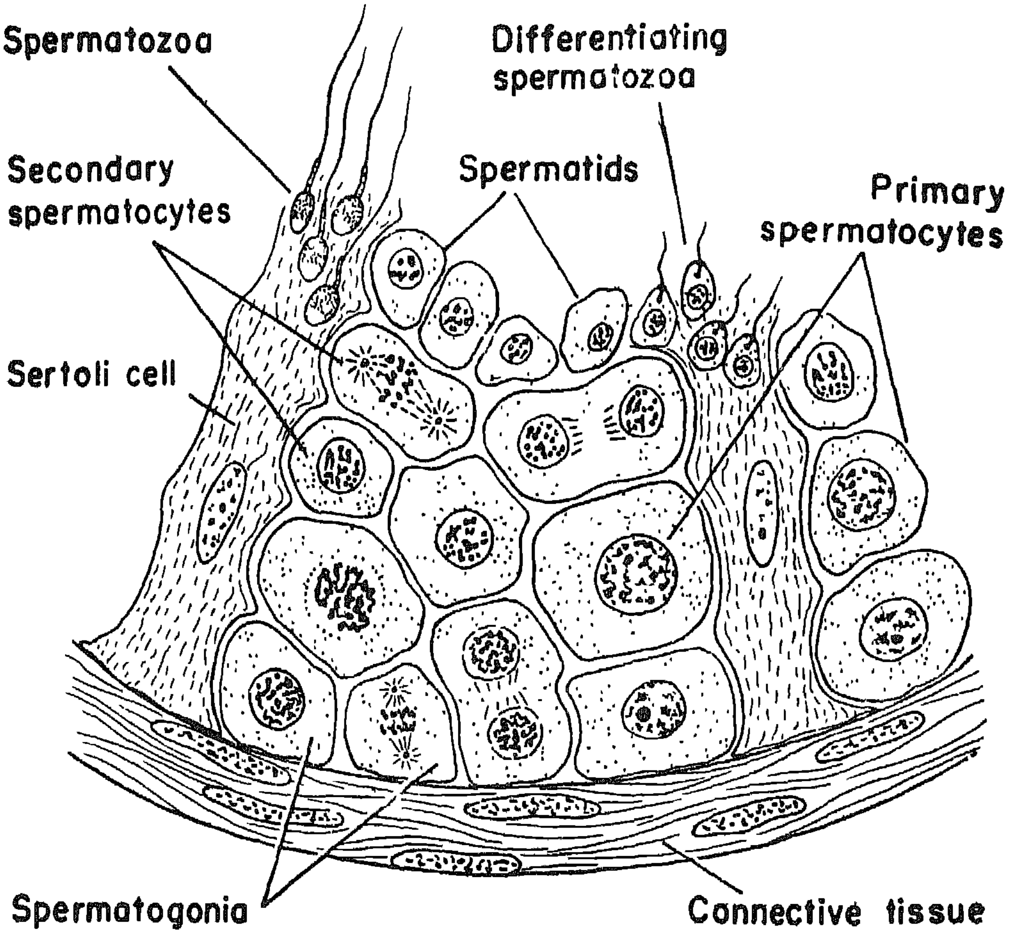


Fig. 18.3 Semi-schematic cross-section through a small part of a semi-niferous tubule of test is to show spermatogenesis.

birth in mice) and may continue throughout life

Ova—The Female Gametes

Structure of Ova

In all animals, ova or eggs are single cells, each surrounded by a membrane called the *vitelline membrane*. This is the *primary membrane* produced within the ovary during the formation of the ovum. After release from the ovary and during its passage through the oviduct and uterus, however, the ovum often becomes surrounded by other membranes which are called *tertiary membranes*. These membranes are formed from materials secreted by cells of the walls of the oviducts. The layers of the jelly around the ova of amphibians, layers of albumen (the egg white), shell membrane and the porous calcarious shell surrounding the ovum (or the yellow yolk

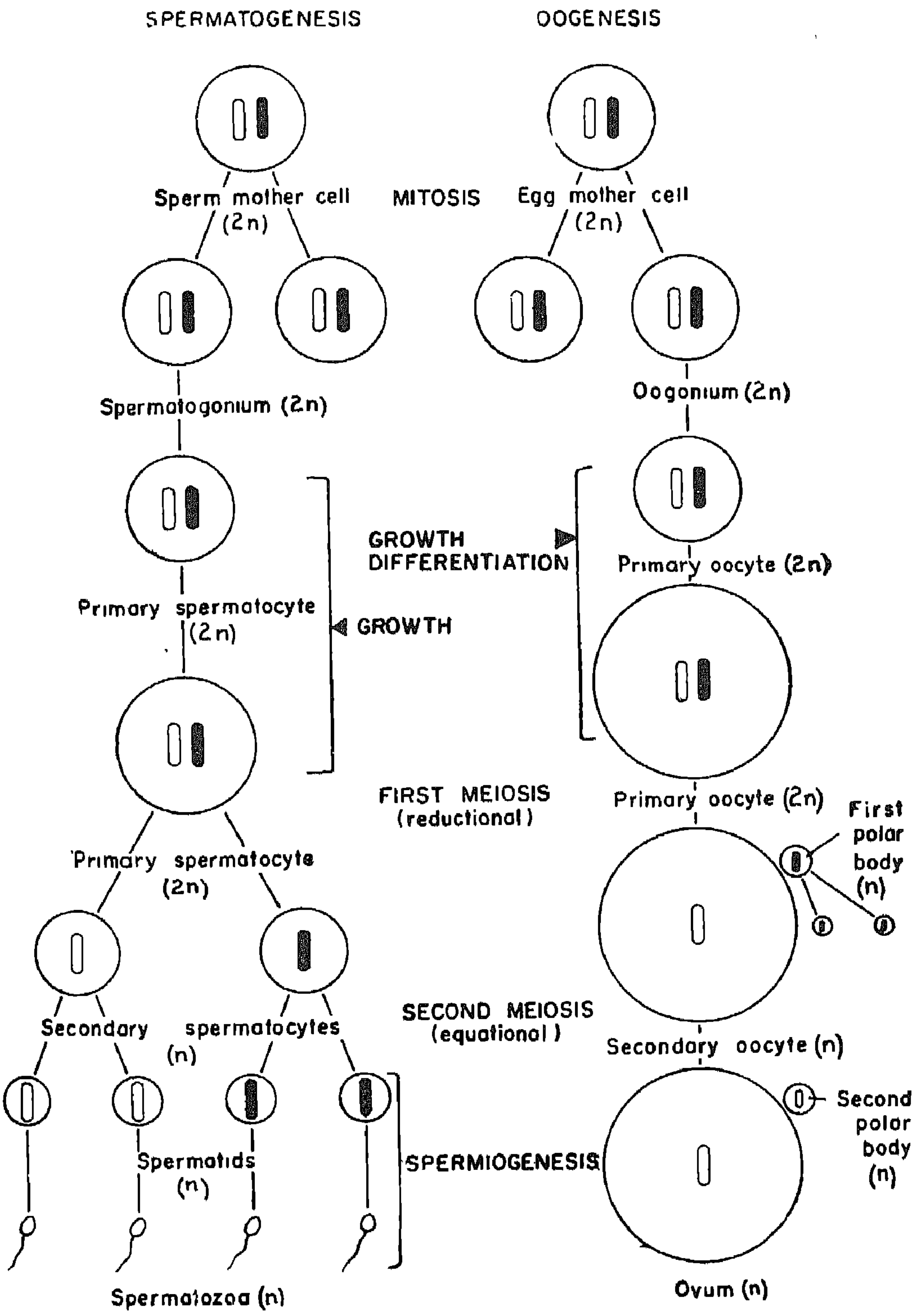


Fig. 18.4 Spermatogenesis and oogenesis in animals.

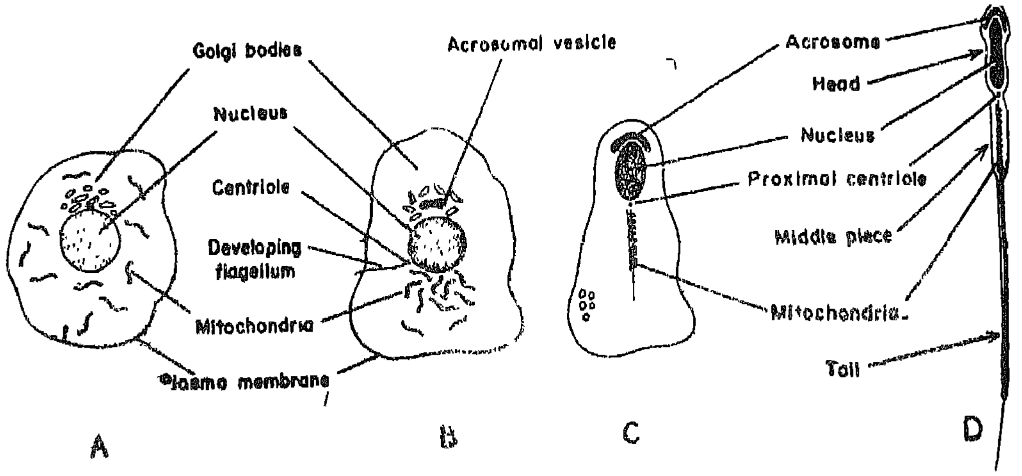


Fig. 18.5 Spermiogenesis: (*A*) Spermatid; (*B*) & (*C*) Intermediate stages of transformation of spermatid into a sperm; (*D*) Differentiated sperm.

as it is conventially called) in the chick egg are examples of such tertiary membranes which are produced in the oviduct

Although the size of the egg varies in different groups of animals, a mature ovum in all animals is much larger than any other type of cells.

Most animal eggs are spherical, but on close examination it is found that one pole of this spherical body is different from the opposite pole. During the formation of the ovum, small daughter cells, called *polar bodies*, are given off at one particular pole which has come to be called the *animal pole*. The opposite pole is known as the *vegetal pole*. The egg is, therefore, said to have *polarity*. The line passing through the two poles is the *primary axis* or animal-vegetal axis of the egg. The various cytoplasmic substances are distributed along the axis in a somewhat unequal manner, forming a gradient which also is an indication of polarity of the egg. For example, in frog the egg yolk is largely concentrated towards the vegetal pole and diminishes in quantity towards the animal pole.

Types of Eggs

All animal eggs contain some reserve materials to provide food and building material for the development of the embryo Mostly, these reserves are in the form of yolk, lipid, glycogen, etc While some eggs contain so little that they are translucent, others are opaque with densely packed yolk.

According to the quantity of yolk present, the following types of eggs are found in the animal kingdom (Fig. 18 6) :

(a) *Microlecithal (or oligolecithal)*— Eggs containing a small amount of yolk. Examples. tunicates, amphioxus, sea urchins In marsupials and eutherians mammals, the ova are almost without any yolk and are, therefore, often referred to as *alecithal.*

(b) *Mesolecithal*: Eggs containing a moderate amount of yolk. Examples : petromyzon, lung fishes (Dipnoi), salamanders, frogs, toads (amphibia).

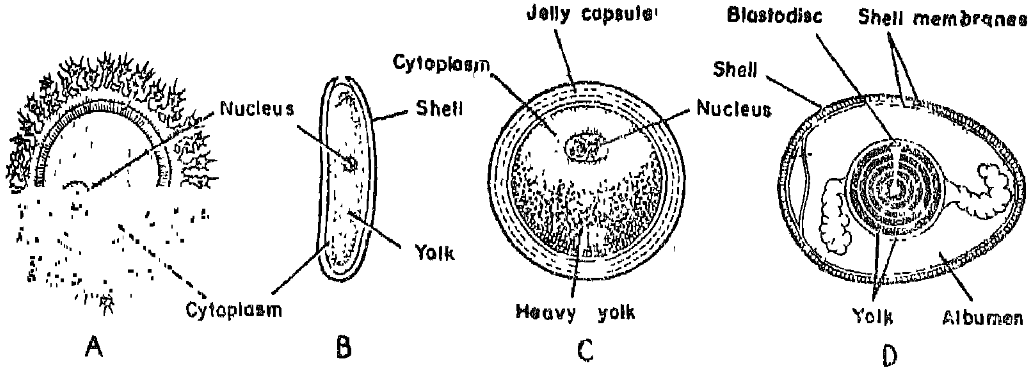


Fig. 18.6 Types of eggs: (*A*) Microlecithal or almost alecithal (mammal); (*B*) Centrolecithal (insects); (*C*) Mesolecithal (amphibian); (*D*) Highly telolecithal (birds).

(c) *Macrolecithal (megalecithal or polylecithal)*: Eggs containing enormous quantities of yolk. Examples: sharks, bony fishes, reptiles, birds, prototherian mammals, insects.

The distribution of yolk within the ovum is also not similar in all types of eggs. In the alecithal and microlecithal eggs, the yolk is evenly distributed throughout the cytoplasm and such eggs are called *isolecithal* or *homolecithal*. In the mesolecithal and macrolecithal eggs, the yolk is concentrated more in the vegetal hemisphere and most of the active cytoplasm along with the nucleus is displaced to the animal hemisphere. Such eggs are referred to as *telolecithal*. In the macrolecithal eggs, for example, of birds, the amount of yolk is so great that it occupies almost the entire ovum, confining the active cytoplasm and the nucleus to a small caplike area around the animal pole. In the insect eggs, the yolk is concentrated in the centre of the ovum with the cytoplasm surrounding it. Such eggs are called *centrolecithal*.

Oogenesis

The process of formation and maturation of ova is called *oogenesis* and it is fundamentally similar in all animals. Differences, if any, are minor and are related to whether the ova produced are with or without the yolk

The ova are derived from the germinal epithelium lining the ovary Some cells in this epithelium are larger than others and have bigger nuclei. These are the *primordial germ cells* or *egg mother cells* They divide repeatedly by mitosis to produce a large number of daughter cells called *oogonia*, which also divide to produce more oogonia. Groups or clusters of oogonia thus formed in the ovary adjacent to the germinal epithelium are called *ovigerous cords*. After the divisions have stopped, the oogonia are then called *oocytes* but only some of them ultimately develop into ova. These oocytes enter the phase of growth and differentiation and are called *primary oocytes* Most of the remaining oocytes in each cluster become *follicle cells* which surround the developing ovum and provide nourishment to it.

The phase of growth and differentiation of the primary oocytes is a long one. In frogs, it takes three years for the young oocyte to reach the ultimate size. In human females, all the oocytes needed for the entire reproductive period of a woman are already present at the time of birth.

However, the primary oocytes remain small without any growth for 12-14 years until the girl reaches the age of puberty or sexual maturity. As noted earlier, the amount of growth of the primary oocyte is very great, with the size increasing from several hundred to several thousand times in different animals.

During the phase of growth and differentiation of the primary oocyte, many changes take place in the cytoplasm and also the nucleus. A thin vitelline membrane is secreted around the oocyte. The mitochondria increase in number, the endoplasmic reticulum becomes more complex and the golgi bodies produce many granules which accumulate under the vitelline membrane and form a dense cortex Food reserves in the form of yolk and other materials are synthesized and stored in the oocyte. The nucleus enlarges, the number of nucleoli increases indicating enhanced activity of the DNA and the nucleus becomes filled with a larger quantity of nuclear sap.

After the primary oocyte has attained its full size, it undergoes the first meiotic or maturation division. The nucleus moves to the animal pole and divides by meiosis. One of the two cells formed after this division is very small, containing the nucleus but extremely little cytoplasm. This small cell formed at the animal pole is called the *first polar body*. Almost the entire cytoplasm with its constituents and all yolk remain within the other larger daughter cell now called the *secondary oocyte*. This first meiotic division is reductional so that both the larger secondary oocyte and the small first polar body are haploid.

The secondary oocyte becomes the ovum after the second meiotic division. This division like the first occurs at the animal pole and results in two extremely unequal cells. The smaller of these, the *second polar body*, also receives the nucleus but only very little cytoplasm, whereas the larger cell, now called the *ovum*, gets most of the cytoplasm and all yolk. The second meiotic division, however, is equational as far as the chromosomes are concerned so that the nuclei of the second polar body and of the ovum remain haploid. Meanwhile, the first polar body may also divide and so a total of three polar bodies are formed.

Thus, from one oogonium there develops only one large ovum possessing a haploid set of maternal chromosomes and a sufficient quantity of yolk and other food materials. The other three daughter cells derived from the same oogonium are the three small polar bodies. Of these four daughter cells obtained from an oogonium, only one, the ovum, is the functional gamete capable of further development; the polar bodies have no such capacities and soon die. In most vertebrates, the first meiotic division occurs within the ovary, converting the primary into the secondary oocyte; but the latter completes the second maturation division much later only after the sperm has entered it at fertilization. In many invertebrates, on the other hand, both maturation divisions are completed within the ovary which releases (ovulation) fully mature ova.

In the ovaries, not all oogonia become ripe and mature ova at the same time. Instead, groups of eggs mature together in a batch, while the other batches of oocytes remain quiescent. Most animals have well-defined one or more breeding seasons.

Fertilization

With few exceptions, the ovum after leaving the ovary becomes relatively inactive. In order to become active again and to begin further development, it needs a stimulus which is normally provided by the entry of the sperm into the ovum, called *fertilization*. In some cases, however, eggs do need fertilization and continue to

develop into new individuals Such development is called *parthenogenesis* which occurs naturally in several animals and can also be brought about artificially in some others. More will be said about this phenomenon, later.

Fertilization involves the union of a sperm and an ovum to produce a single cell, zygote, from which the body of the offspring is formed Fundamentally, it performs two functions:

(i) The sperm's contact with and entry into the ovum activates the egg. This activation is manifested in the egg completing the second meiotic division and in many other changes leading to the next phase of development, i.e., cleavage.

(ii) The fusion of two haploid nuclei, one from the sperm and the other from the ovum, restores the diploid condition in the zygote nucleus and the individual developed from it contains the normal specific diploid number of chromosomes like its parents. In this way, the embryo and the resulting offspring receive both paternal and maternal characteristics through the sperm and egg nuclei, respectively.

Site of Fertilization

Fertilization of the ova occurs either outside the body of female parents (external fertilization) or inside the oviducts of the female into which the sperms are introduced by the male by means of an intromittant organ (penis in mammals) during copulation or mating (internal fertilization).

Whether fertilization is external or internal is correlated with the structure of the eggs produced and on the location of the development of the embryo in the animal concerned. The eggs produced may (a) consist of the ovum surrounded by only a vitelline membrane, one or more layers of follicle cells or a soft jellylike material through which the delicate sperms can penetrate to reach the ovum (most aquatic invertebrates, tunicates, many fishes, frogs and toads), or (b) the ovum may be covered by a calcareous shell too hard for the sperms to pierce through (insects, reptiles, birds, egg-laying mammals). With respect to the location of the development of the embryo, the animals are either (a) *oviparous* in which the eggs develop outside the body of the female parents, (b) *ovoviviparous* in which the eggs are retained within the uterus of the mother where they develop until hatching and birth, or (c) *viviparous* in which the ova become implanted in the uterine wall and develop there until birth (Fig. 18.7).

External fertilization occurs in those animals which are oviparous, lay eggs in water and in which the ovum is not surrounded by any hard covering. Or, if there is a shell, it has an aperture called *micropyle* through which the sperms can enter to reach the ovum, as in the case of certain fishes. *Internal fertilization* is the rule in animals whose development is ovoviviparous (certain lizards and snakes, scorpion, some fishes), viviparous (marsupial and placental mammals, including man) and also in those which, although oviparous, lay eggs covered by hard shells (insects, most reptiles, birds, egg-laying mammals). The sperms, on being introduced into the female genital tract, travel up to the proximal part of the oviducts where they meet the ova and fertilize them before any other membranes or shells are secreted around the ova. In human females, fertilization of the ovum occurs in the oviduct or *fallopian tube* after which the fertilized ovum travels down into the uterus where it gets implanted or attached to its wall.

An important need to be fulfilled for fertilization to take place is that the

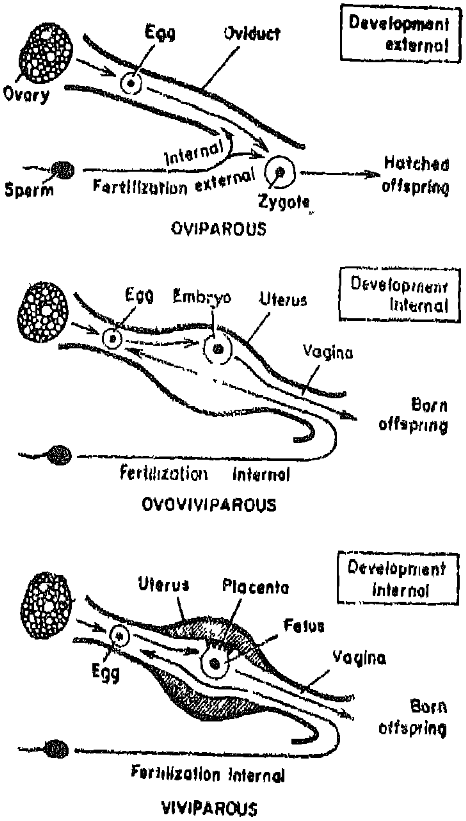


Fig. 18.7 Sites of fertilization and embryonic development in oviparous, ovoviviparous and viviparous animals.

sperms must reach and make contact with the ova. The general opinion is that the movement of the sperms is quite random in all directions and it is purely by chance that some of the huge number of sperms released happen to make contact with, and fertilize, the eggs while others perish. The discharge of the huge number of sperms by the males increases the chance that at least some sperms will collide against the eggs and fertilize them. During one mating amongst humans, about 350 million sperms are ejaculated, by the man into the vagina of the woman; but out of these millions only a small number reach the fallopian tubes and only one succeeds in fertilizing the ovum waiting there.

Mechanism of Fertilization

The act of fertilization consists of three main steps: (i) penetration of the sperms into the egg, (ii) activation of the ovum, and (iii) fusion of the sperm and egg nuclei (Fig. 18.8).

Parthenogenesis

Development of an egg without fertilization by a sperm is called *parthenogenesis*. In a number of invertebrates, it occurs naturally (natural parthenogenesis) and it is a normal part of their life cycle In some like aphids, phyllopods and rotifers, parthenogenetic development of eggs occurs only in some parts of the year and produces only females. In bees and wasps, some eggs develop without fertilization and produce only males, while others are fertilized and produce females. Drones (males) of a honey bee colony are produced parthenogenetically from unfertilized eggs. Among vertebrates, natural parthenogenesis has been reported in domestic turkeys among birds. In this species, about 40 per cent of the unfertilized eggs may develop in this way, some up to hatching and all the young produced in this way are males. Among reptiles, a lizard (*Lacerta saxicola armaniaca*) found in the Caucasian region of the Soviet Union is reported to reproduce exclusively by parthenogenesis and in this species only females are found in nature.

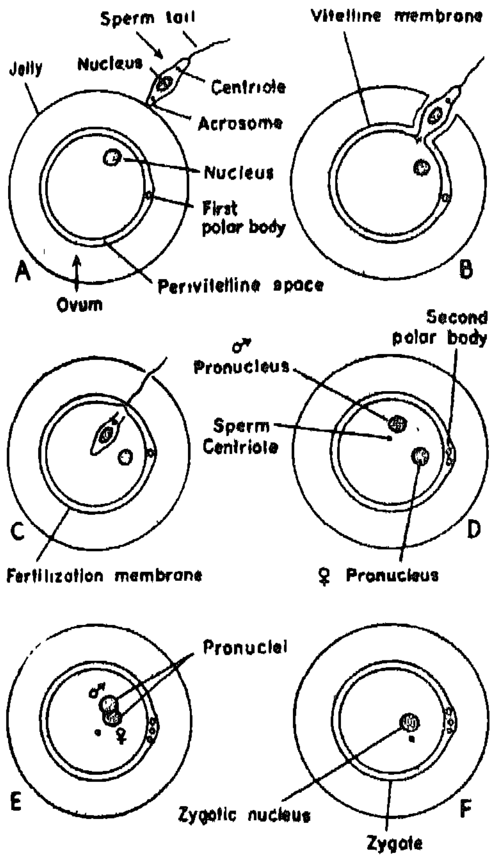


Fig. 18.8 Schematic figures showing processes and events in the fertilization of an egg by a sperm.

Parthenogenetic development of eggs can also be induced artificially in certain animals by various means *(artificial parthenogenesis)*. Thus, the unfertilized sea urchin eggs can be made to develop successfully by treating them with various salts (chlorides of potassium, sodium, magnesium, calcium, etc.), weak organic acids, some fat solvents (benzene, ether, etc.), urea, sucrose, electric or temperature shocks or by simply vigorously shaking them in sea water. An unfertilized frog egg can be induced to develop successfully by pricking the egg with a glass needle smeared with blood. Attempts have also been made to induce parthenogenetic development in the eggs of some mammals. However, in these animals although the eggs after various treatments do start cleaving, development is abnormal and does not proceed very far. In rabbits, a few cases of the young born from the eggs induced to develop parthenogenetically by artificial means have been reported but these reports need confirmation.

The fact that eggs can develop to complete adults without fertilization demonstrates that the ovum within itself contains all the factors necessary for development and only needs a stimulus to activate it. Normally in sexually reproducing animals, this stimulus is provided by the entry of the sperm into the ovum at fertilization, but in some cases it is not needed even naturally, and in some others it can be provided by artificial means.

Cleavage

The fertilized, activated egg or zygote is still a single cell. It is, therefore, necessary that it must first be converted into a multicellular body having a sufficient number of cells with which to start building the complex body of the offspring. It is like collecting a large number of bricks before beginning the construction of a house. In the zygote, this is achieved by a series of rapid cell divisions until many cells are produced. The phase of embryogenesis consisting of rapid cell divisions following fertilization is called *cleavage*. The mitotic divisions during this phase are called *cleavage divisions* and the resulting daughter cells are known as *blastomeres*. Cleavage begins soon after fertilization and ends with the formation of a blastula.

Characteristics of Cleavage

The cleavage divisions of eggs in all animals share some common characteristics.

(i) All divisions are mitotic and occur rapidly one after the other; but their rate depends upon the species concerned and on temperature.

(ii) During cleavage, there is no growth in the resulting blastomeres and the total size and volume of the embryo remains the same. The zygote is much larger than the typical body cell and as a result of successive divisions during which there is no growth, the size of the blastomeres is progressively reduced to that of the ordinary body cells. In this respect, cleavage divisions are different from the usual mitotic divisions occurring in the later embryo and adults in which each division is followed by a period of growth of the daughter cells before the latter divide again.

(iii) In the zygote, the size of the cytoplasm is proportionately much greater as compared to that of the nucleus and so the nuclear/cytoplasmic ratio is very low. During cleavage while the size of blastomeres decreases progressively, nuclear size remains the same. As a result, the nuclear/cytoplasmic ratio increases and ultimately becomes the same as in the ordinary cells of the adults.

(iv) During cleavage, the blastomeres do not move and so the general shape of the embryo does not change except for the formation of a cavity in the interior.

(v) Early cleavage divisions occur synchronously, i.e., all blastomeres present divide simultaneously. Such synchrony disappears after a few dozen blastomeres have been formed.

(vi) For rapid nuclear divisions, there is very great increase in the synthesis of DNA needed for duplication of chromosomes

(vii) Oxygen consumption is greatly increased during cleavage.

Patterns of Cleavage

During cleavage, the division furrows are not formed in haphazard directions but are oriented in some regular manner with reference to the primary animal-vegetal axis of the egg. The orientation of successive cleavage furrows with respect to each other and to the primary axis of the egg is, however, not the same in all species. Therefore, various patterns of cleavage are found among animals, of which three patterns are particularly common, viz., radial, bilateral and spiral (Fig. 18.9).

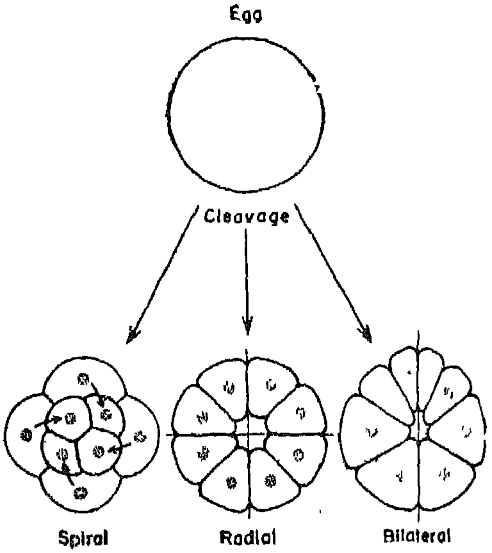


Fig. 18.9 Semi-schematic figures showing spiral, radial and bilateral patterns of cleavage in animal eggs.

Radial: In this cleavage, pattern divisions take place in such a way that all the blastomeres are placed in a radially symmetrical manner around the animal-vegetal axis (sponges, coelentrate, some echinoderms).

Bilateral: In this pattern of cleavage, radial symmetry is lost and the blastomeres are so arranged that the right and

left sides become apparent (vertebrates cephalopod mollusks and some echinoderms).

Spiral: In this pattern of cleavage, the furrows are so formed that the blastomeres are arranged in a spiral manner around the animal-vegetal axis (flat worms, annelids, most mollusks).

Types of Cleavage

Cleavage is influenced by the quantity and pattern of distribution of the yolk in the egg (Fig 18.10). This is because the yolk is inert material and it retards the progress of the furrow to divide the cytoplasm following nuclear division. Accordingly, the following basic types of cleavage are found in animals:

(i) *Holoblastic cleavage:* When the furrow divides the egg or blastomeres completely, it is called holoblastic cleavage It is (a) *equal* if the daughter blastomeres are of equal size as it happens in most microlecithal or isolecithal type of eggs, or (b) *unequal* if the daughter blastomeres are unequal in size. This is the case with the telolecithal eggs of frogs and some fishes in which the third cleavage gives rise to four small and four large blastomeres. The smaller blastomeres are called *micromeres* and the larger ones *macromeres* or *megameres*.

(ii) *Meroblastic cleavage:* In the polylecithal or macrolecithal eggs, the yolk displaces the active cytoplasm to a small area near the animal pole or around the periphery of the egg. Divisions occur only in this cytoplasm and the yolk is not affected at all. This is called *meroblastic cleavage* and is one of two types:

(a) *Discoidal:* In the highly telolecithal eggs, cleavage occurs only in the cytoplasmic disc on the top of the yolk near the animal pole forming a disc of several layers of cells (reptiles birds, egg-laying mammals)

(b) *Superficial.* In the centrolecithal type of eggs of insects, at first the nucleus located in the centre of the yolk divides repeatedly. The daughter nuclei then migrate through the yolk ino the peripheral cytoplasm which then divides into many cells, each with one nucleus, disposed around the yolk below the vitelline membrane.

Blastula

Towards the end of cleavage the rate of cell divisions slows down and blastula is gradually formed. The types of blastula vary a great deal among different animals depending upon a variety of factors such as the size of the egg, the amount and distributional pattern of its yolk and type, the rate and number of cleavage division, etc. (Fig. 18.10). However, the various types of blastulae can be placed in four categories: (i) *stereoblastula,* (ii) *coeloblastula,* (iii) *discoblastula,* and (iv) *superficial blastula.*

Stereoblastula and Coeloblastula

These types of blastula are developed from the holoblastic eggs.

Stereoblastula: This type of blastula is composed of densely-packed but larger-sized and relatively small number of cells without or with extremely small blastocoelic space in the centre. Stereoblastula occurs in a variety of animals such as insects, some worms *(Nereis)* and some mollusks *(Crepidula).*

Coeloblastula: This type of blastula consists of one or several layers of numerous cells arranged around a spacious blastocoel

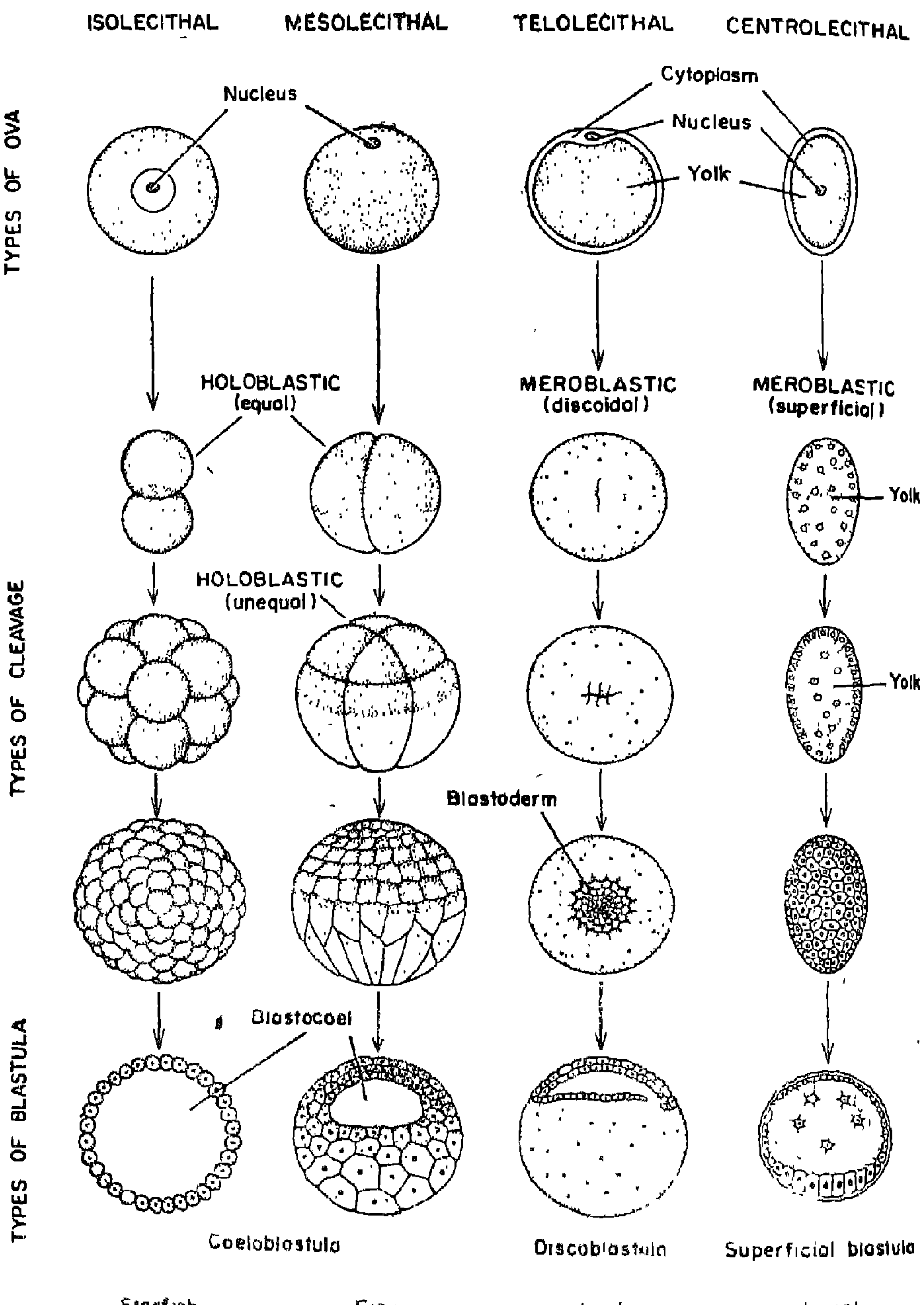


Fig. 18.10 Types of cleavage and blastulae related to the types of animal eggs.

which may be centrally placed or may be eccentric.

Discoblastula and Superficial Blastula

These types of blastula are developed from the meroblastic eggs.

Discoblastula: It is found in some fishes, reptiles, birds and egg-laying mammals. In these animals, eggs are highly telolecithal and the type of cleavage is discoidal which results in the formation of a disc of several layers of cells over the top of the yolk. The disc becomes separated from the yolk by a space called sub-germinal space. Soon, the bottom layer of the cells of this disc becomes separated from the upper layer and a space appears between them which represents the blastocoel.

Superficial blastula: This type of blastula is found in insects and some other arthropods whose eggs are centrolecithal with a superficial type of cleavage. This type of blastula consists of a single layer of epithelial cells surrounding the centrally placed yolk and there is no blastocoel.

Gastrulation: the Beginning of Morphogenesis

The initial steps to lay the basis for the ultimate development of the body form and the formation of different tissues, organs and organ systems in their proper positions are taken during *gastrulation* which follows cleavage and blastulation.

At the beginning of gastrulation, the embryo (blastula) is a hollow or solid ball of cells or a disc of several layers of cells. By the end of gastrulation, however, the embryo, now called a *gastrula*, consists of three layers of cells: (i) an outer layer *(ectoderm)*, (ii) an inner layer *(endoderm)* surrounding a cavity, called *archenteron* and (iii) an intermediate layer *(mesoderm)* between the other two layers. This arrangement of cells is brought about as a result of very complex but orderly and co-ordinated movements and shifting of positions of large masses of cells.

During gastrulation, the cells initially located in one region of the surface of blastula remain on the outside but spread around the embryo to form the outer layer, the ectoderm. A mass of cells from another region moves inward and forms the inner layer, the endoderm, surrounding a cavity called *archenteron* which is the lumen of the future alimentary canal. Groups of cells from still other regions also migrate into the interior and take up positions between the ectoderm and the endoderm and form the intermediate layer, the mesoderm. Meanwhile, the original blastocoelic cavity disappears. These three layers of cells are known as the *primary germinal layers* and are arranged in specific positions with respect to each other. They are the initial rudiments of all future tissues and organs of the body.

Gastrulation may then be defined as that phase of embryonic development during which cell movements establish the three primary germinal layers and initiate morphogenesis of the body.

Gastrular Movements

The movements of the cells which bring them to specific positions where they form different structures are called *formative* or *morphogenetic movements.*

The gastrular movements are broadly of two basic kinds: *epiboly* and *emboly.*

Epiboly involves stretching and spreading movement of the ectoderm, forming cells to surround the embryo on all sides except at one end where an aperture called the blastopore is formed.

Emboly means the process of endodermal and mesodermal cells becoming internal and it may take place in one of the following four methods:

(i) *Invagination:* This is the simplest

method in which the vegetal pole side of the blastula simply caves in or pushes into the interior just as it happens on the side of a soft rubber ball when it is poked with a finger.

(ii) *Involution:* Active in rolling of endodermal and mesodermal cells from the surface into the interior

(iii) *Ingression.* Separation of individual cells from the vegetal pole area or from the ectodermal or endodermal cells and their migration into the interior.

(iv) *Delamination:* Separation of whole sheets of cells from each other.

The most important features of gastrulation in all animals are :

1. Complex but orderly and irreversible morphogenetic movements involving large masses of cells
2. Rearrangement of cells as a result of the above movements to establish the three primary germinal layers.
3. Formation of the archenteron surrounded by the endoderm
4. Little growth so that the overall size of the embryo does not increase significantly.
5. Greater activity of the nucleus and the formation of new proteins

EXERCISES

1. Define the following terms: (1) Gametogenesis, (2) Fertilization, (3) Cleavage, (4) Gastrulation, (5) Morphogenesis, (6) Differentiation, (7) Hermaphrodite, (8) Parthenogenesis.
2. List the main phases of embryonic development and write a short note on each.
3. Differentiate between (1) egg and embryo, (2) blastula and gastrula, (3) stereoblastula and coeloblastula, (4) internal fertilization and external fertilization, (5) spermatogenesis and oogenesis.
4. Distinguish between oviparity, ovoviviparity and viviparity.
5. Briefly describe the process of spermatogenesis
6. Briefly describe the process of oogenesis.
7. What are the similarities and differences between spermatogenesis and oogenesis?
8. What is the significance of fertilization?
9. List the basic characteristics of cleavage divisions. How do these divisions differ from ordinary mitosis?
10. Write short notes on·
    (1) Structure of sperm, (2) Types of eggs, (3) Parthenogenesis, (4) Sites of fertilization, (5) Significance of gastrulation.

CHAPTER 19

Development of Frog

THE PROCESSES and events during the development of individuals in sexually reproducing metazoa are basically similar. However, at the beginning of studies in developmental biology it is essential that a student should first thoroughly understand the development of one suitable animal. In all countries, frog has always been chosen as the most suitable animal with whose life history the science of developmental biology is introduced to the beginners.

Breeding Seasons

All frogs breed in the water of pools, ponds, lakes, etc., and are seasonal breeders. Their breeding seasons depend mainly upon humidity and temperature, and perhaps on the genetic factors also in some species. India is a vast country with a variety of climatic conditions and so the breeding seasons of frogs in different parts of the country are not exactly the same. The Indian bull frog, *Rana tigrina*, breeds during monsoon starting from about the end of June.

Mating Calls

When the breeding season comes, the males reach the water first and start croaking by inflating their vocal sacs which are especially well-developed at this time. These mating calls or croaking of the male frogs are heard only during the breeding season and not at other times of the year

Amplexus

The mating calls of the male attract the sexually mature female. The male climbs on the back of the female and clasps her with his fore limbs under her arm pits. This sexual embrace of the male and female frogs is called *amplexus*. The nuptial pads on the first finger of the hands of the male are very prominent during the breeding season. These swollen pads assist the male in gripping the female firmly. Amplexus usually occurs in rather shallow water.

Ovulation and Spawning

Generally, frogs become sexually mature about three years after metamorphosis when the ovaries contain the first generation of fully-developed *primary oocytes* The first meiotic division is now completed and the eggs in the stage of *secondary oocytes* are released into the body cavity by rupture of the ovarian wall. This phenomenon is known as *ovulation*. By the ciliary action of the peritoneum the eggs

are driven into the oviducts through their funnel-like openings called the *ostia*. They pass down the oviducts to accumulate in the uteri. A thin layer of jellylike material is secreted by the glandular walls of the oviducts around the eggs as they travel through these ducts (Fig. 19.1).

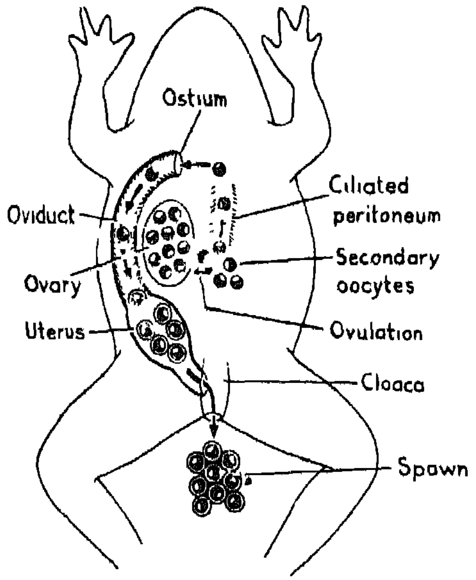


Fig. 19.1 A schematic figure showing ovulation into the body cavity, passage of the eggs through the oviduct, their accumulation in the uterus and spawning in the frog.

Spawning is the act of laying of eggs by the female frog stimulated by the male during *amplexus*. The frog eggs are laid in a cluster or *spawn* containing from a few hundred to several thousand eggs depending upon the species. A single spawn of the Indian bull frog, *Rana tigrina*, may contain 3000-4000 eggs. The frog spawn can easily be recognized from that of toads whose eggs are arranged in a single file which may be several metres in length.

The diameter of the egg of different frog species varies from about .75 to 2.5 mm. The unfertilized egg is spherical and surrounded by a thin, transparent vitelline membrane (Fig. 19.2). The surface of one-half of the egg is pigmented gray, brown or black (animal hemisphere) while that of the other half is white or pale-yellow (vegetal hemisphere). The centre of the animal hemisphere is the *animal pole* and that of the other hemisphere is the *vegetal pole*. The first polar body may be seen at the animal pole just below the vitelline membrane. The frog's egg is *mesolecithal* as it contains a moderate amount of yolk. It is also *telolecithal* because of unequal distribution of the yolk along its animal-vegetal axis with most of it concentrated in the vegetal hemisphere. The nucleus and most of the active cytoplasm is displaced into the animal hemisphere.

Fertilization

Fertilization is *external* and occurs in water. It involves penetration of a sperm (Fig. 19.3) into an egg and is accomplished within a few minutes after the eggs and sperms are released. In the case of delay, the jelly capsule around the egg becomes too thick for the sperm to pass through it and the egg also starts showing degenerative changes with the loss of power for development.

The sperm becomes attached to the jelly capsule and dissolves it by its acrosomal secretion. This facilitates the sperm to pass through the jelly up to the vitelline membrane which also breaks at the point of contact. The sperm always penetrates into the egg in the animal hemisphere near the animal pole (Fig 19.4). Only the head and the middle piece enter the interior of the egg and the tail is left behind. Normally, only one sperm enters the egg to form the zygote.

Cleavage

Cleavage or *segmentation* consists of a series of repeated mitotic divisions of the fertilized egg (zygote) occurring very

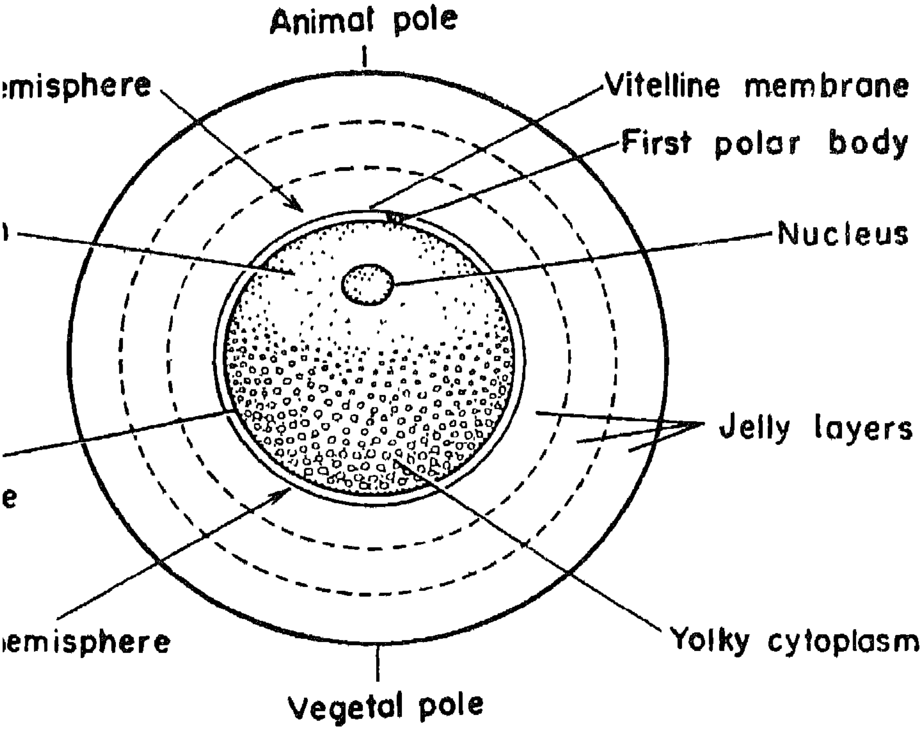
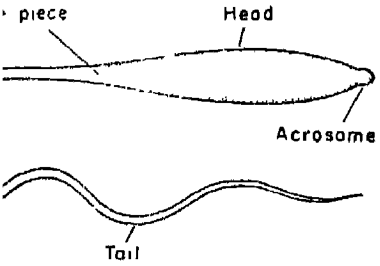


Fig. 19 2 An unfertilized egg of frog.



. 19.3 A sperm of frog.

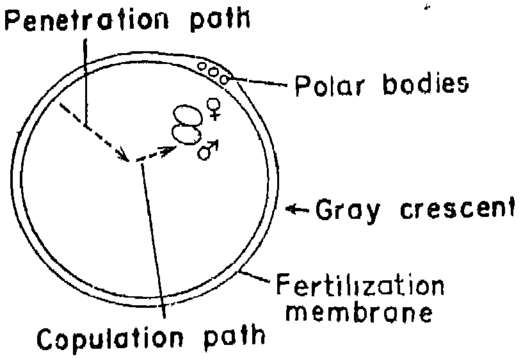


Fig 19.4 Penetration and copulatory paths of the sperm nucleus in the egg during fertilization. The position where gray crescent is formed is indicated by an arrow.

after the other. These divisions convert the single cell zygote ow multicellular *blastula*. The e holoblastic as their furrows egg completely. The *first clea-* ridional passing through both

nd *cleavage* is also meridional ow is at right angles to the first.

The *third cleavage* is latitudinal and the furrow is formed in the animal hemisphere slightly above the equator. It results in the formation of eight *blastomeres* arranged

in two tiers of four cells each, the four smaller and pigmented blastomeres of the upper tier are the *micromeres* and the four larger yolk-laden blastomeres of the lower tier are the *macromeres* (Fig. 19 5).

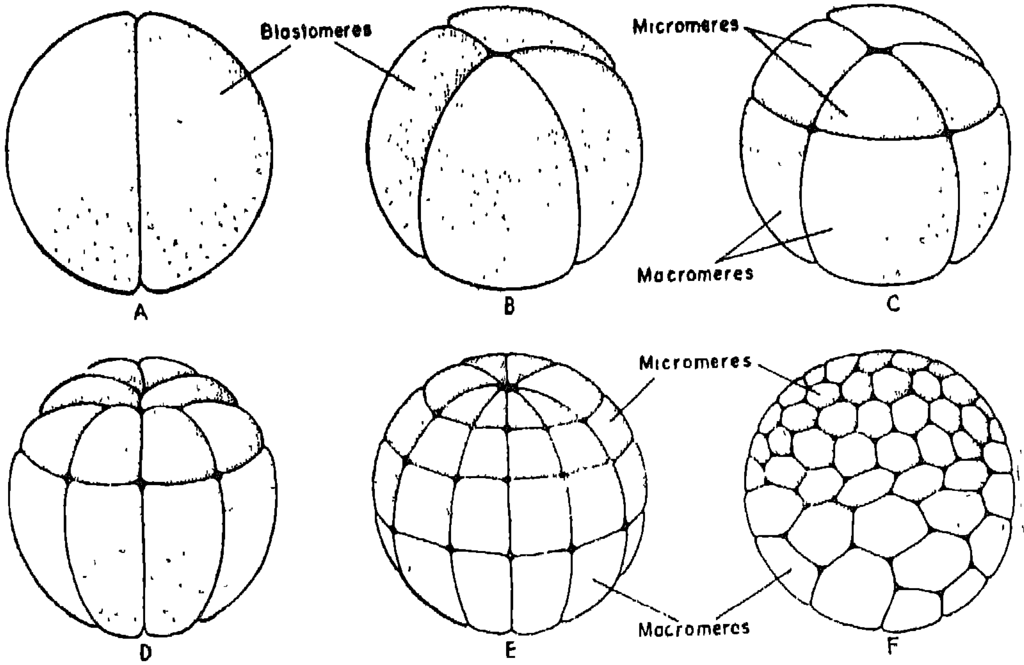


Fig. 19.5 Stages during cleavage in a fertilized frog egg: (*A*) First cleavage (2 cells); (*B*) Second cleavage (4 cells); (*C*) Third cleavage (8 cells); (*D*) Fourth cleavage (16 cells), (*E*) Fifth cleavage (32 cells); (*F*) Morula.

During the *fourth cleavage*, all blastomeres divide along a vertical plane, producing a 16-cell embryo. In the *fifth cleavage*, the blastomeres divide more or less latitudinally, resulting in a 32-cell stage of the embryo.

The divisions after the fifth cleavage become very irregular and asynchronous, i.e , all blastomeres do not divide at the same time and their division furrows are also formed along all sorts of planes The micromeres divide faster than the macromeres. The relatively slow divisions of the macromeres is due to the presence in them of a large amount of yolk The cleavage results in the formation of the embryo with a large number of cells, among which micromeres are far more numerous than macromeres

Blastulation

After the *sixth* or *seventh cleavage* division, the embryo looks like a mulberry-shaped ball of cells which is often referred to as the *morula* stage (Fig. 19.5) The inner ends of the blastomeres become rounded, producing a space between which is the beginning of a cavity called the *blastocoel*. It is eccentric and displaced towards the animal hemisphere The blastocoel gradually enlarges because of secretion into it of albuminous material from the surrounding cells and absorption of water from outside. Meanwhile, the cells which are constantly increasing in number and

decreasing in size become compact and form an epithelium around this cavity. Although not easy to comprehend, they are very coordinated and always produce

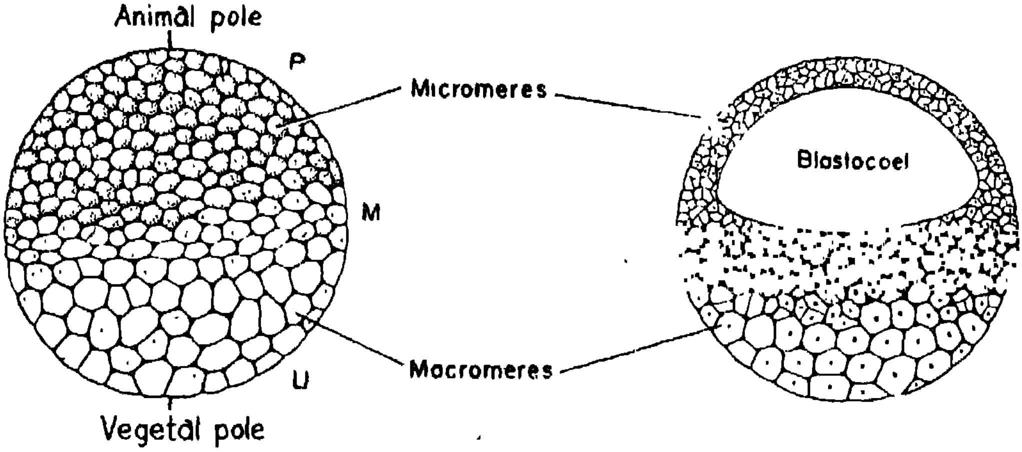


Fig 19.6 Frog blastula: (*A*) External view—*P*, pigmented zone; *M*, Marginal zone, *U*, unpigmented yolky zone; (*B*) Cross section

Cleavage ends with the embryo becoming a *blastula* (Fig. 19.6)

Gastrulation

The end of cleavage and the formation of blastula is followed by the next phase of development called *gastrulation* which converts the blastula into a *gastrula*. During gastrulation, blastocoel disappears, as a new cavity, *archenteron*, is formed. The archenteron becomes the lumen of the future alimentary canal. At the blastula stage, the cells are all arranged around the blastocoel; but in the gastrula, they are arranged differently in the form of three distinct germinal layers—an outer *ectoderm* on the surface surrounding the embryo, an inner *endoderm* around the archenteron, and an intermediate mesoderm located between these two layers.

The Process of Gastrulation

The period of gastrulation is marked by mass movements and rearrangement of cells These movements in frog are very complicated and occur simultaneously the same result.

Gastrulation begins with the formation of a shallow crescent-shaped grove in the vegetal hemisphere on the posterior side just below the lower border of the gray crescent. The embryo at this stage is called the *early gastrula*. This groove is the beginning of the archenteron and its upper edge is called the *dorsal lip of the blastopore*. This groove gradually deepens and extends laterally on either sides so that it becomes horseshoe-shaped. Its lateral edges are called the *lateral lips of the blastopore* Ultimately, the groove becomes circular and a *blastopore* is formed whose ventral edge is called its *ventral lip*. The blastopore at this stage encloses the unpigmented zone of yolky cells which protrude out through it, forming the *yolk plug*. At this stage, the embryo is known as the *yolk plug gastrula*. Later, the protruding yolky cells get into the inside of the embryo and, simultaneously, the lips of the blastopore gradually constrict, finally reducing it to a vertical slit By this time, the entire

embryo is externally covered by a sheet of dark pigmented cells.

These internal changes during gastrulation include formation of the archenteron, disappearance of the blastocoel and establishment of the three primary germinal layers (Fig. 19.7).

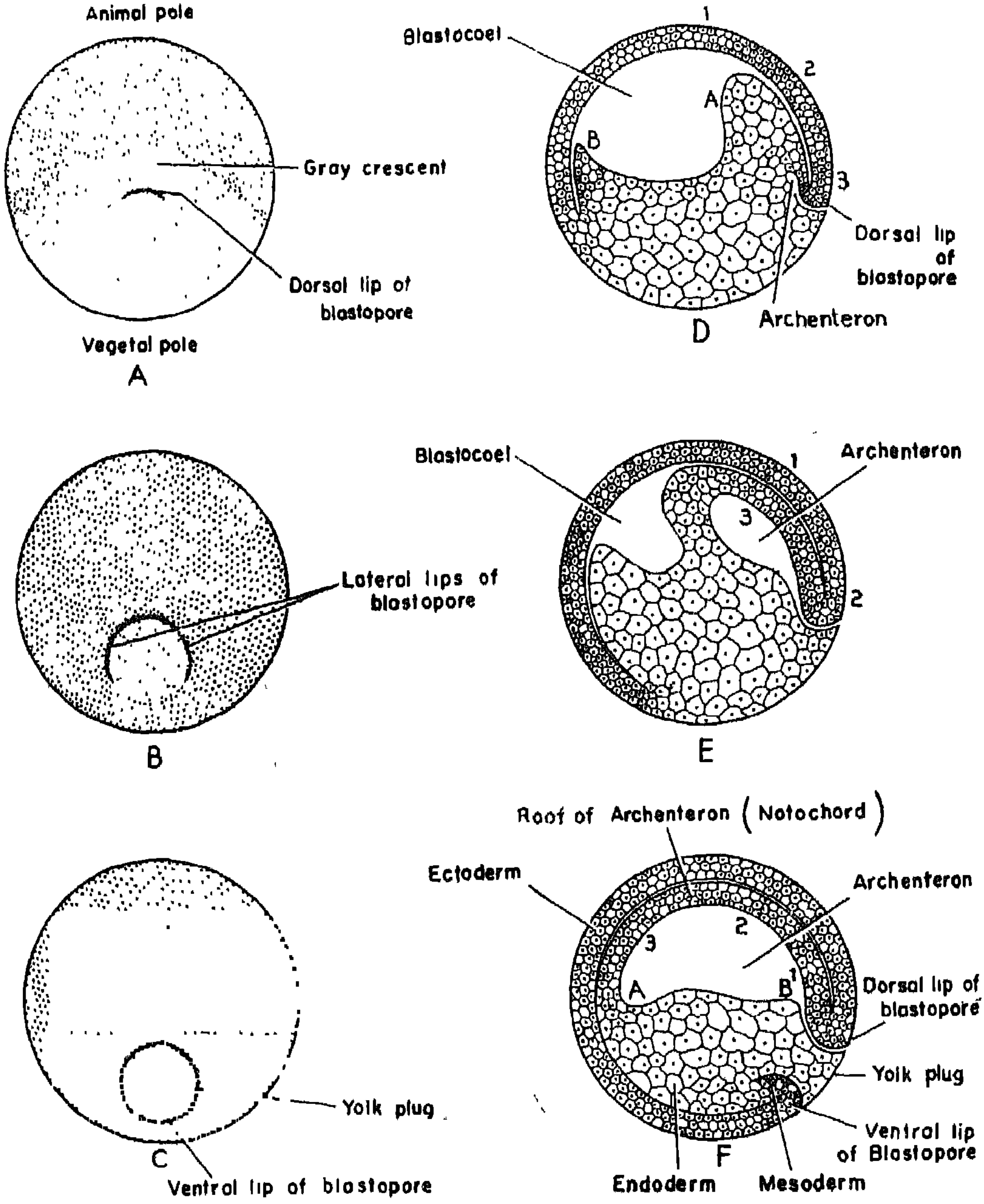


Fig. 19.7 Gastrulation in frog: Early gastrula—(*A*) external view, (*D*) cross section; Midgastrula—(*B*) external view, (*E*) cross section; Late gastrula—(*C*) external view, (*F*) cross section.

In short, it can be said that during gastrulation (i) cells of the future notochord become internal by active movements over the dorsal lip of the blastopore to form the mid-dorsal region of the roof of the archenteron (Fig. 19 8); (ii) cells of the rest of the future mesoderm migrate also by involution over the lateral and ventral lips of the blastopore and then diverge antero-

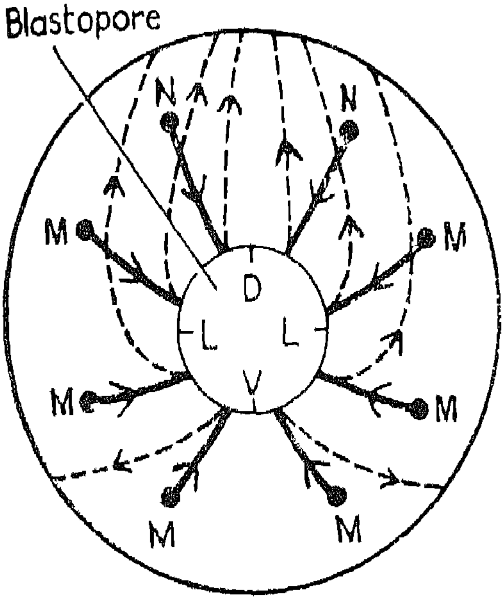


Fig. 19.8 Schematic figure to illustrate movements of mesodermal (M) and a Notochordal (N) cells during gastrulation in frog Thick lines and arrows indicate movements on the surface towards the blastoporal lips and thin broken lines with arrows indicate movements inside the gastrula away from the blastoporal lips. D, dorsal lip; L, lateral lips; and V, ventral lip of the blastopore.

dorsally to form a mesodermal layer dorso-laterally on each side between the endoderm and the ectoderm, (iii) the endoderm becomes internal partly by invagination but mainly by the ectoderm spreading over it The presumptive endodermal mass rotates on itself with the forward extension of the archenteron whose floor and sides are formed by it; (iv) the ectoderm is formed by the epibolic movements of the cells of the presumptive ectodermal region, which stretch and spread as a sheet to cover the entire embryo externally

During the entire process of gastrulation, the embryo remains more or less spherical with very little increase in its size

It should be noted that with the formation of the gastrula, the basis for the structural body plan common to all metazoans, i e , a tube within a tube, is laid down. The ectodermal layer forms the outer tube, enclosing the inner tube consisting of the archenteron surrounded by the endoderm

Fate of the germinal layers

During further development after gastrulation, the various tissues, organs and organ systems are formed gradually from cells derived from one or the other of the three primary germinal layers. What structures will be formed from cells of any germinal layer is called the fate of that particular layer. A list of tissues, organs and organ systems derived from the ectoderm, mesoderm and endoderm, respectively, is given in Table 1 which indicates the fate of each of these layers

TABLE 1

List of tissues, organs and organ systems developed from the primary germinal layers, ectoderm, endoderm and mesoderm

Ectoderm	*Mesoderm*	*Endoderm*
1. Epidermis	1. Dermis	1. The mucus lining of the entire alimentary canal from the pharynx to the hind gut
2. Nervous system (Brain, spinal cord, nerves)	2. Muscels (Skeletal, smooth, cardiac)	2. Glands of the stomach and the intestine
3. Pigment cells	3. Most bones and cartilages	3. Tongue
4. Part of the visceral and cranial cartilages	4. Kidneys	4. Liver
5. Medullary portion of the adrenal gland	5. Gonads	5. Pancreas
6. Posterior and intermediate lobes of the pituitary gland	6. Urinary and genital ducts	6. Thyroid gland
7. Pineal gland	7. Cortical part of the adrenal gland	7. Anterior lobe of the pituitary gland
8. Eye (Retina, lens, cornea)	8. Coelomic epithelium	8. Thymus gland
9. Nasal epithelium	9. Connective tissues	9. Parathyroid gland
10. Internal ear	10. Blood vessels	10. Ultimobranchial bodies
11. Lateral line sense organs	11. Heart	11. Lung and gills
12. Stomodeum (Buccal cavity)	12. Lymphatic system	12. Primordial germ cells
13. Proctodeum (Rectum)	13. Spleen	

Neurulation

During this phase of embryogenesis which follows gastrulation, the embryo starts growing in size, elongates antero-posteriorly and the shape of the body begins to appear. At first, the embryo assumes an oval shape with the broad end posterior and the narrow end anterior. Later, it becomes laterally compressed while its growth in length continues. The slit-like blastopore closes during neurulation. Other changes during this period are chiefly concerned with the beginning of the formation of different tissues and organs or organogenesis. *Neurulation is, therefore, a period of the beginning of organogenesis.* The main developments in this respect include (i) formation of the notochord, (ii) formation of the gut by complete encirclement of the archenteron by

the endoderm, (iii) formation of the neural tube, and (iv) differentiation of the meso- derm which splits into rudiments of various tissues (Fig 19.9).

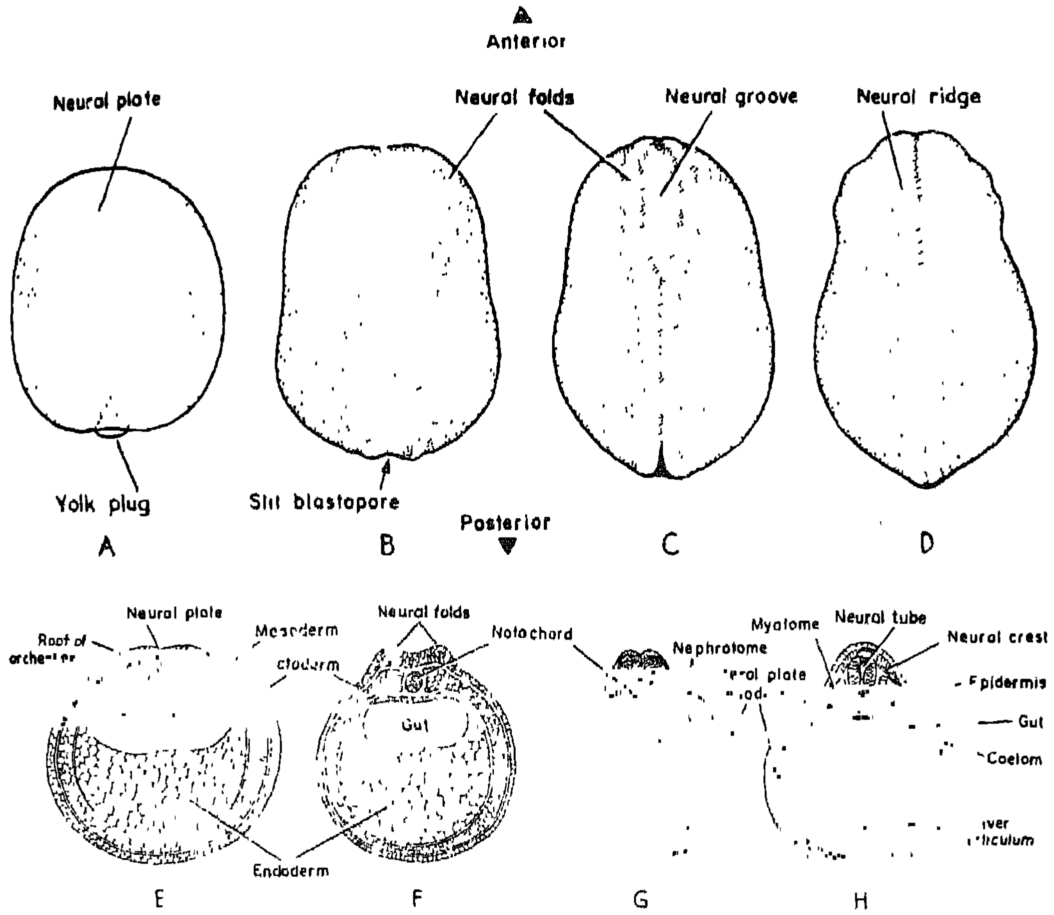


Fig 19 9 Neurulation in frog Neural plate stage— (*A*) external view, (*E*) cross section; Neural fold stage— (*B*) external view, (*F*) cross section; Mid-neurula— (*C*) external view, (*G*) cross section Neurula— (*D*) external view, (*H*) cross section.

All the changes, external as well as internal, go on side by side. This phase of development ends with the formation of a closed neural tube.

Development after Neurulation, up to Hatching

Growth in length, change in shape and organogenesis which started during neurulation continue after the closure of the neural tube and the embryo gradually assumes the shape of a tadpole.

External Development

The embryo is said to be at the *tail bud stage* of development when it is about 2.5-3 mm long. At this time, it has a recognizable head distinct from the trunk and at the hind end a small outgrowth or tail bud has appeared, indicating the beginning of

the tail. Two nasal pits at the anterior end of the head and a small anal pit below the tail bud are now present Small swellings on each lateral side of the head and trunk indicate the positions of the internally developing eyes, gills and kidneys A pair of epidermal thickenings on the ventral side of the head are the rudiments of future adhesive glands or *oral suckers*. A few *myotomes* or back muscles are indicated above the rounded belly by faint grooves The surface of the tail bud embryo is ciliated.

At hatching, the embryo is about 5-6 mm long The head is now very prominent The nasal pits have deepened and a shallow median depression or *stomodeum* has formed at the anterior end of the head The stomodeum is separated from the pharynx by an *oral plate* and, hence, there is still no mouth opening. The optic region is marked by large round swellings, the optic bulges. The oral suckers are well developed In the trunk, the *gill plate* of each side is now divided into three parts, from which external gills arise after hatching. The *pronephric swellings or bulges* are distinct and myotomes are indicated by the < shaped grooves on each side along the length of the trunk and tail. The apex of < is directed anteriorly. The tail is quite prominent and possesses a dorsal and a ventral fin

Hatching

The time taken for the completion of embryonic development from fertilization up to hatching depends upon the species of frogs and on the temperature. At 26-28°C, the embryos of *Rana tigrina*, the Indian bull frog, hatch in about 24 hours, but at a lower temperature and/or in other species this period may be longer The embryo first softens and dissolves the jelly capsule by some enzymes and then hatches by wriggling out of the capsule

On hatching, the embryo attaches itself to the jelly, floating egetation or moss-covered walls of the tanks with its oral suckers Except for short spurts of swimming, it remains in this condition for a couple of days, being nourished from the yolk present in its midgut. During this brief period, the following developments occur

(i) The mouth opens
(ii) *Horny jaws* and rows of *horny teeth* develop around the mouth.
(iii) Three pairs of *external gills* spread out from the gill plate area and then disappear under an opercular fold of the skin
(iv) *Operculum* forms a chamber into which open the internal gills developed by perforation of the pharyngeal gill pouches. The opercular chamber opens to the outside by an aperture called *spiracle* on the left side
(v) *Lens* and *cornea* are formed and the *eyes* become functional
(vi) *Hind limb buds* appear, one on each side of the cloaca
(vii) Adhesive oral suckers disappear.

The embryo is now a free, swimming, actively feeding *tadpole*

Growth of the Tadpole

From a size of 5-6 mm at hatching, the tadpole steadily grows in length until the maximum normal length is attained. This final length depends upon the species of the frog, temperature, food, density of population, etc. The tadpoles of *Rana tigrina* reared in large bowls in the laboratory at 26-28°C and fed boiled spinach grow to a length of about 45-50mm The tadpoles of American green and bull frogs grow to as much as 90-150mm in length

The hind limb buds elongate slowly and then form tiny limbs over a period of several weeks Then there is a rapid growth

in length of these limbs which become stout and functional and help in swimming. The forelimbs develop under the operculum and emerge only during metamorphosis. The lungs appear as buds from the floor of the pharynx, grow and become well developed towards the latter part of the tadpole's aquatic life. The intestine elongates and forms several coils.

Feeding and Aquatic Adaptations of Tadpoles

Tadpoles of the several species of frogs, including *Rana tigrina*, usually remain near the bottom of the pond or lake and are, therefore, mainly bottom feeders. Tadpoles of some other species are surface feeders. The frog tadpoles are herbivorous, feeding on moss, algae, floating vegetations or bottom mud rich in organic matter. They are well adapted for this mode of nutrition. The oral structures, including the horny jaws and rows of horny teeth in the lips around the mouth, are used to scrape the surface of vegetation. The long, very coiled intestine is another adaptation for this mode of nutrition because plant food must stay in the alimentary canal for a longer time to allow full digestion and assimilation than a carnivorous diet.

Tadpoles may become cannibalistic, eating each other in times of crowding, scarcity of food and starvation. In some frog species, this may be a normal habit to supplement their food.

Tadpoles belong to the aquatic phase of the frog's life cycle. The special features which make them adapted for life in water are: (i) fishlike shape of the body, (ii) presence of gills for respiration, (iii) fish-like heart and blood vascular system, (iv) a long broad tail with dorsal and ventral fins for swimming, (v) presence of a lateral line system of sense organs, and (vi) excretion of nitrogenous waste mainly in the form of ammonia.

Metamorphosis

The term metamorphosis is derived from a Greek word "metamorphoun," meaning 'to transform'. In developmental biology, it is defined as transformation of the larva into adult. A larval stage occurs during the ontogenetic development of many invertebrates and lower chordates. The developmental pattern in such animals is: Egg—fertilization or parthenogenetic activation—embryo—larva—adult.

The larval stage is a temporary phase in the life cycle during which the organism may perform a variety of functions. For example, the larval stage may be useful for geographical dispersal of the species, especially if the adults are sessile or sluggish (e.g., many colonial coelentrates, some worms, echinoderms and ascidians); or they may serve as temporary feeding stages during which all the food materials for the subsequent adult stage is obtained and stored (e.g., some insects, such as moths). Or, the larvae may simply represent a developmental stage resembling a corresponding stage of their ancestors from which they have evolved, for example, the frog tadpoles resemble the larvae of fishes. The larvae always differ structurally and functionally from the adults. Frequently, the larvae occupy habitats and have feeding and other habits different from those of the adults (e.g., butterfly caterpillar, mosquito larvae, frog tadpoles).

The larva eventually changes into a miniature adult which then grows to maturity when it can reproduce. This transformation of the larva into adult is referred to as metamorphosis during which many structural as well as physiological changes take place. The changes may be slight, slow and gradual, but in some they are very radical and occur with great rapidity.

Metamorphic changes in Frog Tadpoles

As you already know, tadpole is a fish-like aquatic organism with herbivorous habits and it changes into a semi-terrestrial, air-breathing, carnivorous frog. Metamorphosis of a frog tadpole, therefore, involves very radical changes in morphology, anatomy and also physiology. Early metamorphic changes are manifested in the following features:

(i) Increase in length of the hind limbs.
(ii) Formation of the pelvic girdle
(iii) Disappearance of the cloacal tube.
(iv) Thickening of the skin and formation of the flask-shaped multicellular mucous glands in the epidermis.
(v) Development of the belly muscle.

These changes are rather slow and gradual and occur during the later part of the tadpole's life. Ultimately, the tadpole

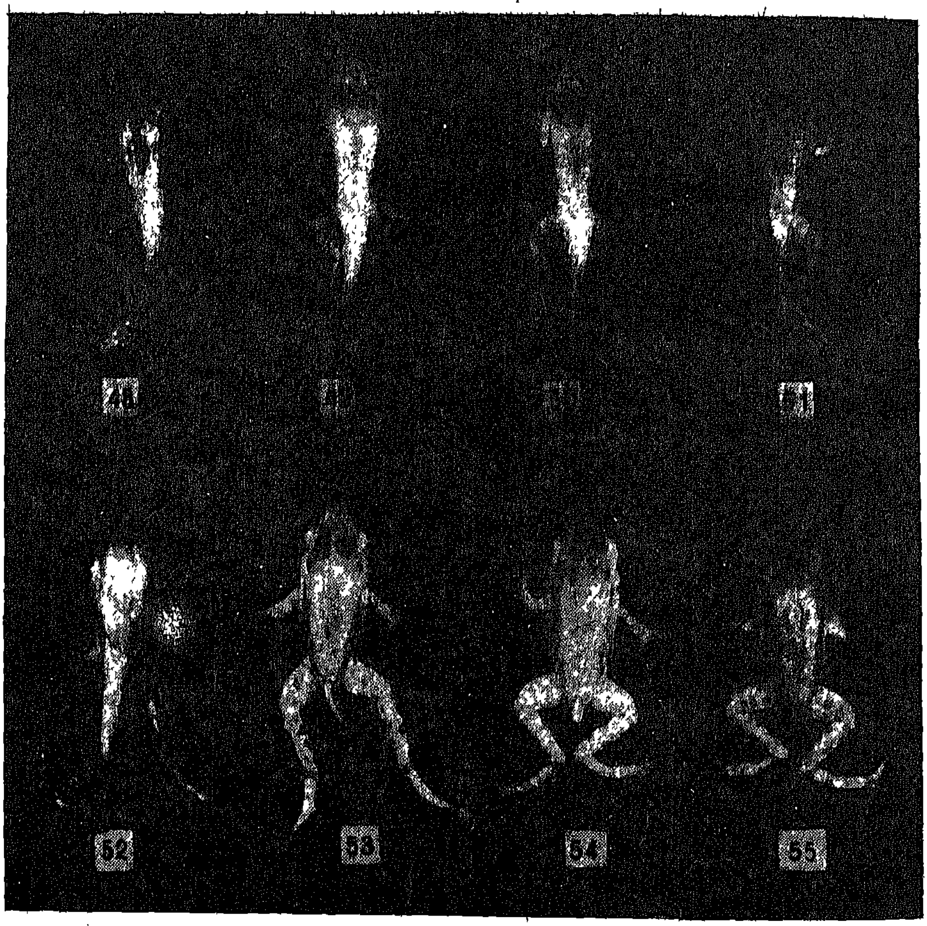


Fig. 19.10 48- Mature tadpole forelimbs visible under operculum. 49 -One forelimb emerged. 50, 51 - Two forelimbs emerged. 52 - Tail reduced to half. 53, 54 - Tail stub 55 -Froglet (metamorphosis complete).

ceases to grow in length any further, stops feeding and enters the phase of *metamorphic climax* (Fig. 19.10).

The *morphological* and *structural* changes which take place during metamorphic climax can be classified into three categories :

(1) *Regressive or destructive changes:* These include the reduction or complete disappearance of those structures which are necessary for the aquatic larval life but are useless for the adults. Among these changes are the following :

(i) Shortening and ultimate disappearance of the tail.
(ii) Disappearance of the larval horny jaws and horny teeth.
(iii) Disappearance of the lateral line sense organs.
(iv) Closure of the gills.
(v) Disappearance of the opercular chamber.

(2) *Progressive or constructive changes:* These include the development of some structures needed for the life of the adult. They are listed as follows:

(i) Great increase in the length and strength of the hind limbs.
(ii) Emergence of the forelimbs
(iii) Enlargement of the lungs.
(iv) Formation of the middle ear and the tympanum.
(v) Development of the tongue and the vomerine teeth.
(vi) Widening of the mouth gap.
(vii) Enlargement of the eyes which bulge up on the head.
(viii) Formation of the nictitating membrane in the eyes

(3) *Modification or remodelling of some structures:* Some larval structures are also useful for adult life but have to be remodelled or modified. Changes of this kind are as follows:

(i) Heart becomes 3-chambered.
(ii) The blood vascular system, which is like that of a fish in the tadpole, is modified with the reduction or disappearance of some aortic arches and increase of blood supply to the lungs and the skin.
(iii) The intestine is greatly shortened in accordance with the subsequent carnivorous feeding.
(iv) Pigmentation pattern of the body changes.

Physiological changes during metamorphosis are many. Some of the important ones of this nature include :

(i) Increased role of the liver in the metabolism of carbohydrates.
(ii) Beginning of the endocrine function of the pancreas with the production of insulin hormone.
(iii) Change from the excretion of nitrogenous wastes in the form of ammonia to the excretion in the form of urea.
(iv) Changes of the larval haemoglobin of blood to the adult type of haemoglobin.

Fig. 19.11 and Fig. 19.12 show some of the landmark stages of *Rana tigrina* during its embryonic and larval development and metamorphosis into a froglet.

Hormonal Control of Metamorphosis: The metamorphosis of the tadpoles of frogs and other amphibians is dependent upon and controlled by thyroxine hormone secreted by the thyroid glands. During the later part of the tadpole stage, the amount of this hormone in the body gradually increases, initiating the early, slow metamorphic changes described above. Towards the end of the tadpole's life, there is a great increase in this hormone which leads to very rapid changes during metamorphic climax.

Metamorphosis in Insects

As mentioned before, the larval stage occurs in the ~~life~~ history of many other

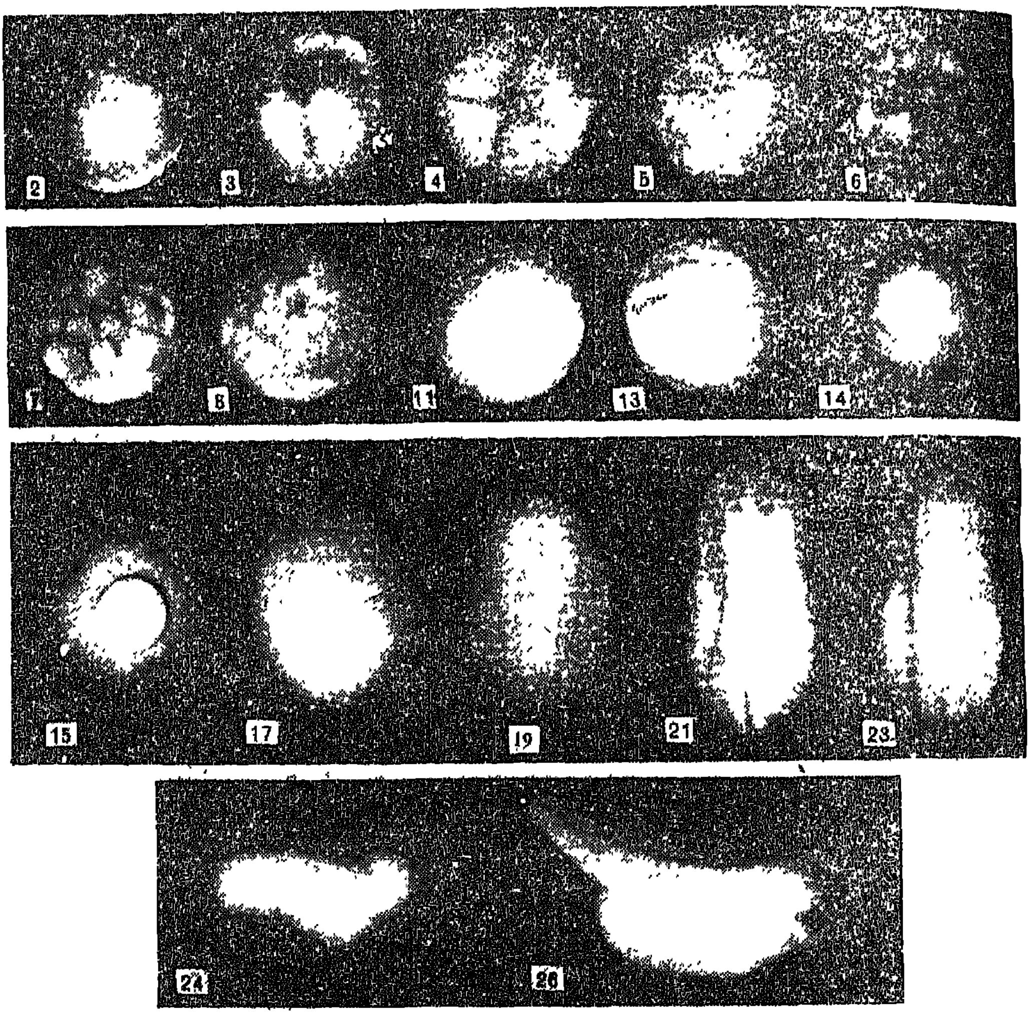


Fig. 19.11 2 - Fertilized egg. 3 - Two celled stage. 4 - Four celled stage. 5 - Eight celled stage. 6 - Sixteen celled. 7 - 32 celled. 8 - Morula. 11 - Blastula. 13 - Early gastrula. 14 - Mid gastrula. 15 - Late gastrula. 17 - Begining of neurulation. 19 - Neural folds. 21 - Late neural folds. 23 - Nourula (closed neural tube). 24 - Tailbud. 26 - Gillbud.

animals also. You may have studied the life history of such common insects as a house fly, a mosquito or a butterfly. In these insects, the fertilized egg hatches into a *larva* which grows for some time and then enters a stage of inactivity when it is called a *pupa*. During pupation, most of the larval organs dissolve and from certain groups of cells adult organs are formed, transforming the larval body into an adult body with different structures, habitat and habits As in the frog tadpoles, metamorphosis in insects also involves both destructive and constructive changes. Like frogs and other amphibians, metamorphosis in insects has also been found to be control-

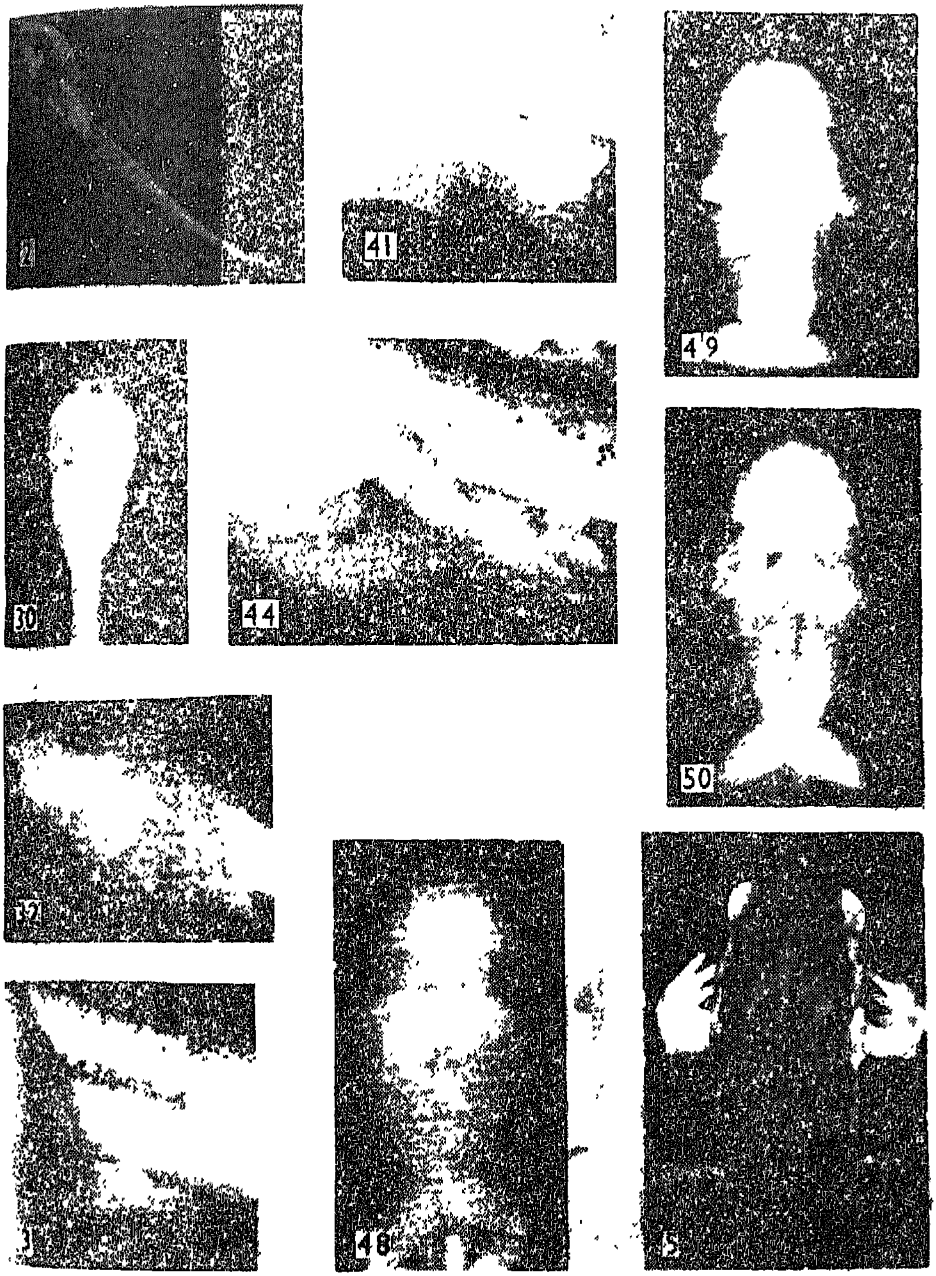


Fig. 19.12 28 - Large external gills. 30 - Opercular fold prominent. 32 - Operculum complete, initial hind limb. 37 Footpaddle. 41 - Rudiments of five toes prominent. 44 Pre-hallux. 48 - Mature tadpole. 49 - One forelimb emerged. 50 - Two forelimbs emerged. 55 - Froglet.
Metamorphosis of the tadpole of the Indian bull frog, *Rana tigrina*, into froglet. Some developmental stages of *Rana tigrina* during embryogenesis. Larval development and metamorphosis in the frog, *Rana tigrina*.

led by hormones. Three hormones are involved in the control of metamorphosis in insects—one from the brain, another from the prothoracic gland and the third from another gland called corpora allata.

EXERCISES

1. Explain the following terms: (1) Amplexus, (2) Ovulation, (3) Spawning, and (4) Spawn.
2. Write notes on: (1) Breeding season of frogs, (2) Mating calls, (3) Cleavage in frog eggs, (4) Tail bud stage, (5) Metamorphosis, (6) Hormonal control of the metamorphosis of the frog tadpoles.
3. Describe the development of frog up to the establishment of the three primary germinal layers
4. What is meant by the 'fate of the germinal layers'? Give a list of structures derived from ectoderm, mesoderm and endoderm in the frog.
5. Describe the process of neurulation during the development of the frog.
6. What is the external structure of the frog embryo at the time of hatching?
7. What developments occur in the frog embryos after hatching upto the formation of operculum?
8. Enumerate the adaptations of the frog tadpole for aquatic life and herbivorous mode of nutrition.
9. Enumerate the structural and physiological changes which occur during the metamorphosis of a frog tadpole.

CHAPTER 20

Embryonic Nutrition

DEVELOPMENT of the embryo involves growth due to increase in the amount of protoplasm and in the number of cells. The embryo needs energy for its various metabolic activities and movement of cells from one position to another. *Supply of the required materials for the synthesis of more protoplasm and other compounds and for the production of energy constitutes embryonic nutrition.* The materials required include amino acids, many minerals, water and oxygen. There are *two* principal ways in which these nutritive materials are made available to the embryo during development until hatching or birth: (1) from food reserves in full or in part in the egg itself during its formation in the ovary or (2) supply of nutritive materials by the mother to the embryo during its entire course of development in the womb.

Supply from Food Reserves in the Egg

This occurs in the eggs of oviparous and ovo-viviparous animals. All the materials required may be stored in the egg, making it almost independent of supplies from outside, or only part of the requirement is stored in the egg and the rest is obtained by the embryo from the surrounding water or other medium in which it develops. All kinds of embryos, however, obtain their oxygen for respiration from outside The storage is usually in the form of yolk, lipids and carbohydrates. The eggs are alecithal, mesolecithal or macrolecithal, according to the quantity of the yolk stored.

Composition of the yolk and other food reserves

The yolk is not one chemical substance but is made of a number of chemicals. Moreover, chemical substances may not be the same in the yolk of the eggs of all species. The main chemical components of the yolk are proteins, phospholipids and, to a lesser extent, neutral fats. If the yolk contains mostly proteins together with a smaller quantity of lipids, it is called *protein yolk* If the yolk consists mainly of phospholipids and fat with some proteins, it is called *fatty yolk*. Both kinds of yolk are present side by side in the eggs of most oviparous and ovoviviparous animals. The protein yolk is the main form of food reserve in many invertebrates and in lower chordates.

Utilization of the Yolk

The mechanism of yolk utilization in

mesolecithal holoblastic eggs like those of frog is simple. During cell divisions, the yolk becomes distributed mechanically into daughter cells. In the cells, it is broken up by enzymes into simpler substances which are then used to synthesize more protoplasm.

In macrolecithal eggs, with meroblastic cleavage, as in birds, the yolk remains outside the body of the embryo which absorbs some of it by diffusion during early stages. Later, a yolk sac develops around the yolk mass from mesoderm and endoderm. Blood vessels called vitelline arteries and veins connect the yolk sac with the heart. Enzymes from the yolk sac digest the yolk into soluble form, which is then taken to the heart and vitelline veins and then distributed to all parts of the developing embryo (Fig. 20.1).

Sources of energy

The embryos obtain energy by oxidation of carbohydrates and fats stored in the egg during oogenesis; or supplied by the mother in the case of viviparous development. The enzymes needed for these oxidation reactions are present in the egg. In the oviparously developing eggs, carbohydrates are the sources of energy during most of the developmental period. Near the hatching time, fats are used as the sources of energy.

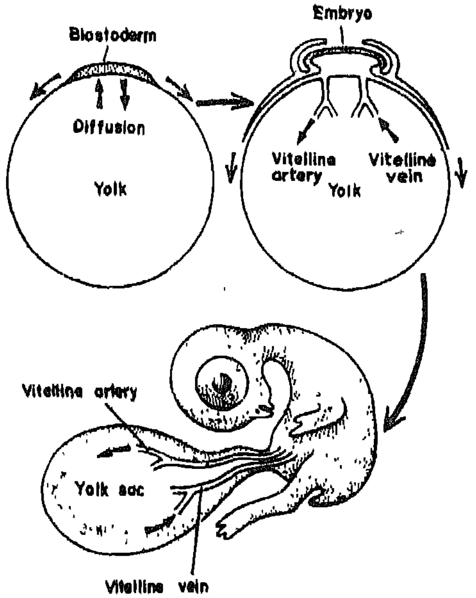


Fig. 20.1 Yolk utilization in chick embryos at different stages of development.

Supply of Nutritive Materials by the Mother

This is in the case of the animals which develop in the viviparous manner within the mother's womb or uterus until birth. Viviparity occurs in many animals but the truest viviparity is found in higher mammals, including man. The egg is almost alecithal with hardly any food reserves worth mentioning. On release from the ovary, it comes into the fallopian tube (oviduct) where it is fertilized.

Implantation

Tht fertilized egg undergoes cleavage and becomes a blastocyst. The blastocyst then moves into the uterus and there it gets connected with or embedded in the thickened wall of the uterus or the womb. This is called *implantation.* It takes from a week or two to several weeks, depending upon the species of the animals, for the embryo to be implanted in the uterine wall after fertilization. In man, the embryo becomes implanted in the wall of the womb in about seven to ten days after the fertilization of the egg. During the period before implantation, the embryo obtains its nutrition by absorption from the uterine secretions in the lumen of the womb in which it lies.

Placenta

After implantation, an organ called

placenta develops which connects the embryo (fetus) to the uterine wall. The process of formation of the placenta is called *placention. The placenta is defined as an organ formed from some parts of the fetus and some from the uterine wall of the mother for exchange of materials between the mother and the fetus.* In the placenta, the mother's blood vessels come close to the blood vessels of the fetus but are always separated by some barriers between them. The nutritive materials and oxygen pass from the maternal blood to the fetal blood through the placenta. The nitrogenous waste and carbon dioxide from the fetal body are passed back from the fetal blood vessels into those of the mother, also through the placenta.

Structure of the placenta · The placenta is made of some parts from the fetus and some from the uterine wall. The simplest type among eutherian mammals is found in cattle like cows, goats, etc. and is known as *epithelio-chorial placenta.* Other kinds of placenta are derived from this basic type. In this placenta, the fetal blood is separated from the maternal blood by six walls or barriers, three of which belong to the fetus and three are from the uterus of the mother (Fig. 20.2). The placenta consists of finger-like projections from the surface of the fetus interdigitating with similar projections and pits of the uterine wall. Between the fetal blood and the maternal blood, the following six layers are present:

Fetal blood

↑ ↓

Fetal components of the placenta:

1. Wall of the fetal blood capillaries (fetal endothelium)
2. Fetal connective tissue
3. Fetal chorionic epithelium

Maternal components of placenta:

4. Mucous epithelium of the uterine wall
5. Uterine connective tissue.
6. Wall of the maternal blood capillaries (maternal endothelium).

↑ ↓

Maternal Blood

The materials and gases from the maternal blood to that of the fetus and back must pass through the above six barriers. In other mammals, one or more of these barriers disappear, bringing the two types of blood closer which makes the passage of materials easier. It also makes the connection between the fetus and the uterus more intimate. In humans, all the uterine components disappear and the maternal blood is separated from the fetal blood only by fetal chorion, connective tissue and endothelium of fetal capillaries.

Physiology of the placenta · The nutritive substances that are transported through the placenta from the mother to the embryo include amino acids, lipids, glucose, fructose, vitamins, water and oxygen and a small quantity of some hormones. The nitrogenous wastes (urea, uric acid) and carbon dioxide resulting from metabolic activities in the embryo are passed back through the placenta to be removed through the mother's excretory systems. Some substances pass through the placenta by simple diffusion and some by a process called active transport. The placenta is an active organ which allows useful substances but prevents most of the harmful ones from passing through it. It also secretes some hormones, such as progesteron, which help in maintaining pregnancy up to the end and preventing abortion or premature birth.

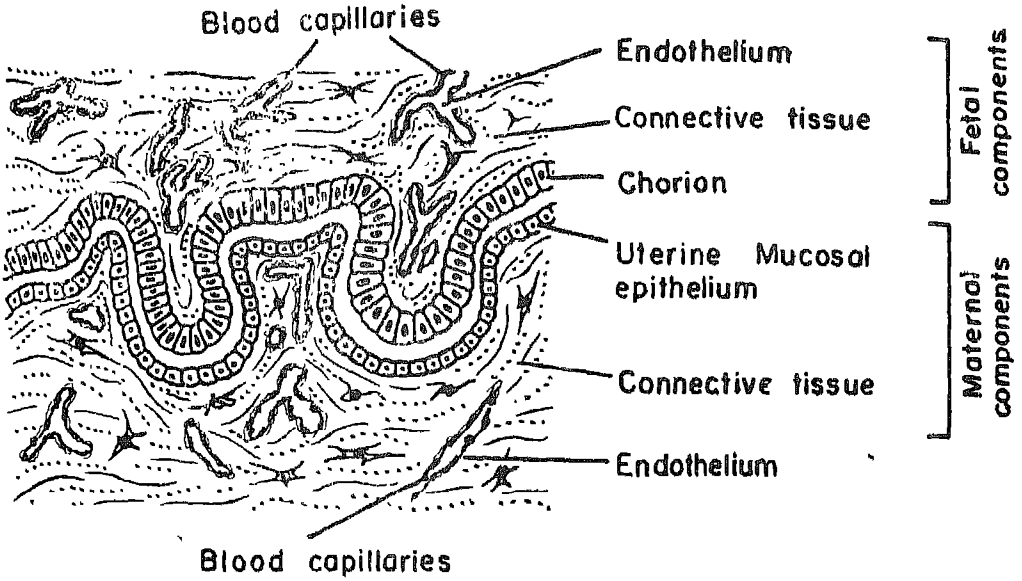


Fig. 20.2 A schematic diagram of a small part of the epithelic-chorial placenta of a pig.

Importance of the Mother's Health During Pregnancy

In viviparous mammals, including man, with alecithal eggs and long period of gestation (i.e., embryonic or fetal development), the mother is the supplier of all the nourishment to the fetus growing in her womb. She also removes the nitrogenous wastes and carbon dioxide from the embryo. The mother, therefore, acts as the stomach, the intestine, the liver, the lungs and the kidneys for the fetus. It should be obvious that good health and proper nourishment of the mother during pregnancy is of extreme importance for the proper development of the fetus. The mother needs nourishment not only for herself but also for building the baby within her.

The fetus needs all the amino acids, vitamins, minerals, carbohydrates, fats, etc., for its development. If the mother's nutrition is poor in any of these required materials, the fetus can and does draw upon the stores from the body of the mother. The maternal tissues may start breaking up to provide raw materials to the fetus and weaken the mother in the process. Deficiencies of vitamins, A, B, C and D in the pregnant mother's diet cause a variety of deformities and deficiencies in the growing fetus. If the mother's diet does not contain enough calcium, her bones start releasing this element for the fetus, and in the end while the mother suffers, the fetus also may not get enough of it and its skeleton may remain fragile.

The growing embryo needs a lot of glucose for energy production. Glucose deficiency of the mother might affect the metabolic activity of the embryo. On the other hand, if there is too much sugar in the mother's blood its level also becomes much too high in the embryo. The large excess amount of sugar is converted into fat which gets deposited in the body of the fetus resulting in abnormalities of various kinds. If the pregnant mother is diabetic the level of sugar in her blood can be very high and it may do harm to the fetus if proper care is not taken to keep the diabetes of the mother under control.

The proper nutrition of the fetus and hence of the mother is particularly important during the latter half of pregnancy. It is during this period that the most rapid growth of the embryo takes place and the need for materials required is very high. However, deficiences of some basic materials in the mother's diet in the early period of pregnancy, may cause, when organ formation begins, many kinds of defects in the fetus.

The most harmful bacteria, viruses and germs and antibodies from the mother are prevented by the placenta from passing into the fetus. However, some of these harmful organisms and also some dangerous drugs are able to get through and reach the fetus and do harm to it. Among them may be mentioned antibodies against Rh factor, drugs like thalidomide, etc., virus of German measles and bacteria of syphilis. The young placenta during the first half of pregnancy is impermeable to bacteria and to large molecules of different substances, but the placenta in the latter part of pregnancy becomes more permeable due to age or due to injuries. Hence, there is greater danger of disease germs from the mother reaching the fetus in the latter half of pregnancy.

Suitable nourishment of the mother and proper care of her health are, therefore, of primary importance for the normal development and growth of the fetus throughout the period of pregnancy.

EXERCISES

1. What are the nutritional requirements of an embryo ? What are the two principal ways by which the embryos obtain their nourishment ?
2. What is the composition of the yolk and how is it utilized by the embryos ?
3. Write a brief essay on the placenta.
4. Write short notes on :
   (1) Energy sources of the embryos
   (2) Implantation
   (3) Physiology of the placenta
   (4) Importance of the health of the mother during pregnancy.

Abnormalities during Embryonic Development

THE PERIOD of embryonic development is full of hazards. A number of factors disturb and distort the normal processes of development. These disturbances may lead to one of the two kinds of results: (i) the embryo may die at some stage of embryogenesis, or (ii) abnormal offspring defective in structure and/or function may be hatched or born. The area of developmental biology concerned with abnormal development during embryogenesis is called *teratology*.

Abnormalities in development can occur due to many different reasons. According to our present knowledge, these abnormalities may be due to genetic causes, damaging external agents or malnutrition.

Fig. 21.1 A group of boys showing *mongolism* (born idiocy) — a hereditary developmental abnormality due to chromosomal error in germ cells.

Abnormalities due to genetic causes

These abnormalities include defects resulting from the increase or decrease in the normal number of chromosomes *(chromosomal errors)* or from *gene mutations*. Most of the abnormalities caused by these factors are so severe that the embryos die before completing the development or shortly after. However, some others are born and survive for long periods. If these defects occur in the somatic cells of only some part of the embryo, they affect only some part of the developing individual. In such a case, the defect does not become inheritable and disappears with the death of the individual.

A well-known defect due to chromosomal error is *mongolism*, also called *mongoloid idiocy*. The individuals born are both physically and functionally born idiots (Fig. 21.1). About one out of 700

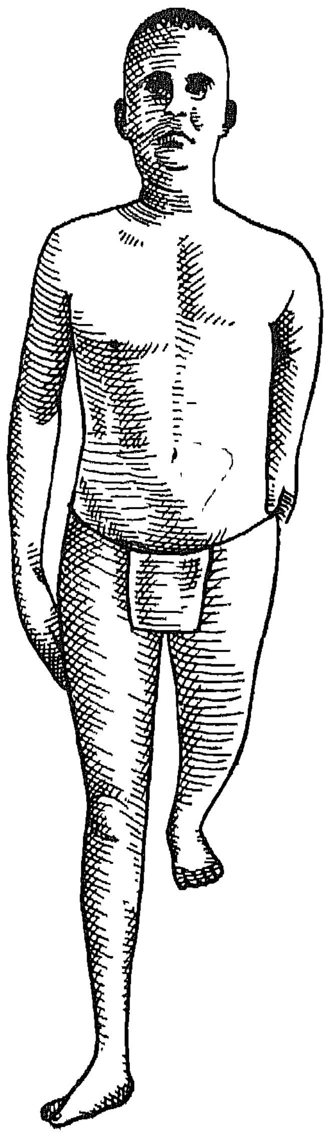


Fig. 21.2 A case of Achondroplasia — hereditary (genetic) developmental abnormality. Right half body normal and left half like that of a dwarf.

births is a Mongol and the number of such born idiots increases with the age of the mother.

Many defects affecting the structure or the function or both are due to ***gene mutations in the germ cells.*** Mutations occur naturally and can also be induced artificially by exposure to X-rays or by chemical substances called mutagens.

Fig. 21.3 *Meromelia* or peg-like limbs without hands and feet — a hereditary (genetic) abnormality of development. The figure shows a father and his son. The mother was normal.

In man, the well-known hereditary defects include *colour blindness, hare lip, cleft palate, club foot, hole in the heart, absence of hands, feet, arms* or *legs,* etc. (Fig.21.2-21.4). Some defects due to gene mutations are called *inborn errors of metabolism.* One example of the inborn error of metabolism is *phenylketonuria.* In this condition, the embryo is not able to utilize protein food properly and one amino acid, *phenylalanine,* and some of its derivatives accumulate to high toxic levels of the body. This results in severe and permanent

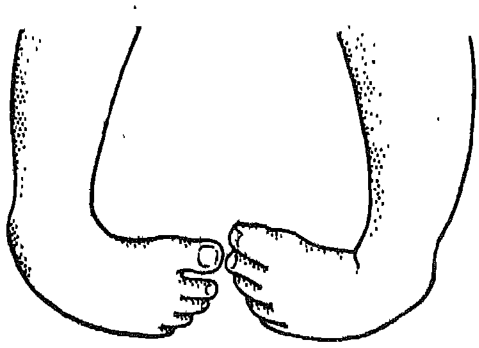


Fig. 21.4 *Club feet*, a hereditary (genetic) developmental abnormality.

retardation of growth and brain development. However, this defect can now be found out early and by a regulated diet the individual can live a normal life. There are many other such inborn errors of metabolism but methods for their early detection and cure are still to be discovered.

Abnormalities due to external damaging agents

A number of disease-producing organisms, chemical substances, drugs, X-rays and other radiations and antibodies produce harmful effects on the embryo or the fetus but they may not affect the mother so much.

For example, if a pregnant woman gets an attack of German measles (rubella) particularly during the period from the third to the twelfth week of pregnancy, the virus of this disease causes severe damage to the fetus. The child may have several defects such as blindness, deafness, mental deficiency due to very small brain, defective heart, hare lip, cleft palate, abnormal intestinal tract and spina bifida (i.e., exposed spinal cord and nerves). In a severe case (Fig. 21.5), death may come early. Among farm animals, several viruses and bacteria (e.g., brucellosis, vibriosis and leptospirosis) cause death and abortion of about 30 per cent embryos. In man, the syphilis germs from the mother result in still birth or congenital abnormalities by infecting the offspring during fetal development.

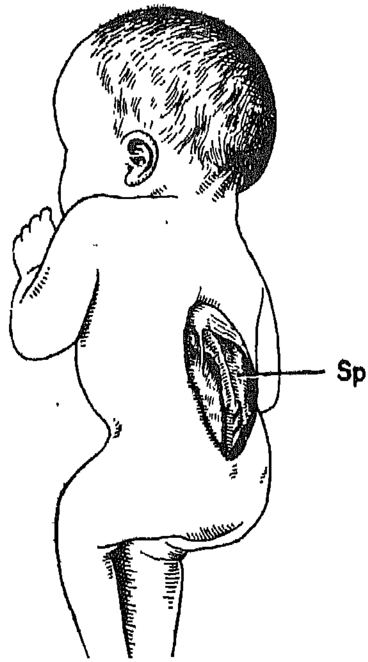


Fig. 21.5 A case of *spina bifida* (exposed spinal cord and nerves), a developmental defect caused by the mother being infected with German measles during pregnancy

As stated above, various chemicals also cause abnormalities in the fetus. These substances include mutagenic agents such as nitrogen mustard and trypan blue, and metabolic inhibitors such as aminopterine and anti-folic acid compounds. Some hormones like cortisone and vitamins like vitamin A, if given in excess to the pregnant female animal during early pregnancy, produce many defects in the embryo. These defects include *hydrocephalus* (greatly enlarged head), *spina bifida* (limb deformities), *ectromelia* (whole limb absent), *phocomelia* (no legs or arms and feet and hands attached to

the body), *cleft palate*, hare lip, etc. Mercury poisoning leads to *cerebral palsy* (paralysis due to damage to the brain) of the fetus. This abnormality is caused if a pregnant woman eats food contaminated with mercury which is released with industrial wastes and may get mixed up with human food.

Various drugs taken by the pregnant mothers especially during the first 12 weeks of their pregnancy also cause much harm to the fetus. These drugs include *quinine* used for the treatment of malaria, *busulphan* for leukemia, *chlorambucil* for Hodgkin's disease, *aminopterin* for abortion, etc *Thalidomide*, a tranquilizer, given to the pregnant women to reduce their vomiting during the period from the fourth to the seventh week of their pregnancy in Germany, England, Canada, and the USA has resulted in the birth of thousands of children without arms or legs (Fig. 21.6).

X-rays and other radiations, too, cause many developmental defects which may be direct or hereditary. Radiations may affect the germ cells of the fetus. The damage in such cases may be expressed after several generations and not in the immediate offspring. Direct effects include damage or defect in one or the other part of the fetus which may be similar to the effects produced by disease germs, chemicals or drugs. If a pregnant woman is to be X-rayed, care should be taken to shield the fetus and protect it from radiations. It should be remembered that young cells, tissues and organs are more sensitive to the effects of X-rays and other radiations.

Abnormal development due to malnutrition

In laboratory mammals like rats, rabbits, etc., and in many other animals also, if the pregnant females are given food deficient in vitamins A, B and D, they may produce very defective offspring. These defects include *hare lip, cleft palate, spina bifida, skeletal defects of long bones,*

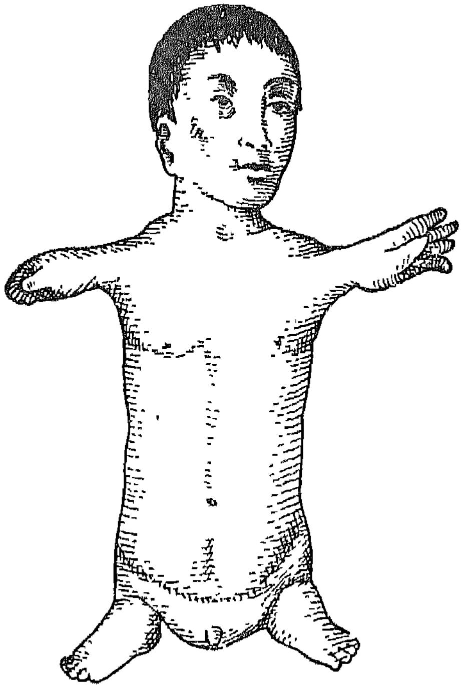


Fig. 21.6 A case of *phocomelia* (no development of long bones of limbs, and hands and feet attached directly to the trunk), a defect produced due to the mother having taken thalidomide during early stages of pregnancy.

vertebral column and skull, eye defects, brain defects, etc. Perhaps, these deficiencies in the diet of the pregnant mothers of the human species may also cause similar harm to the fetus. This is particularly important for our country where malnutrition and even frequent starvation of the pregnant women are still common in a large percentage of our people.

Twins

Normally, a woman gives birth to only one young at a time, but occasionally more than one child is born to a woman at the same time. These are called the cases of *multiple births*. Most commonly,

in the case of multiple births, the number of births is 2 and the individuals thus born together are called twins. However, the number may be 3 (triplets), 4 (quadruplets), 5 (quintaplets) or even more. At least, one case is known of as many as 11 infants being born at a time to the same mother. Multiple births also occur in other animals. Thus, in cattle (cows, sheep, goat, etc.) which normally produce only one young at a time, about five per cent of all births may be twins.

Twins are often completely normal in shape and development. However, some twins may be very abnormal being fused with each other wholly or in part. Such twins are called conjoined twins (Fig. 21.7 A-H). Most of such cases do not survive and the preserved specimens of conjoined twins can be seen in a museum of any medical college or a large hospital.

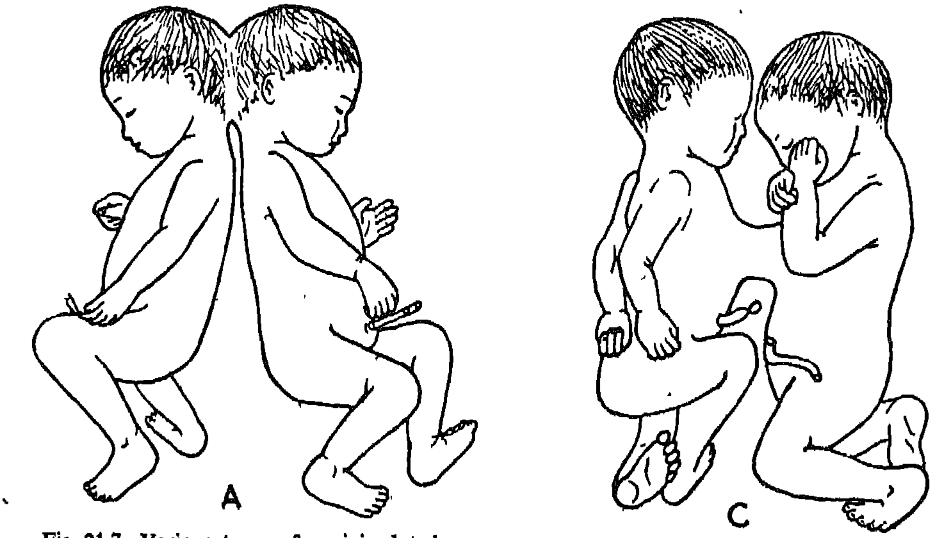


Fig. 21.7 Various types of conjoined twins.

Twins may be *monozygotic* or *dizygotic.*

Monozygotic twins

The first type of twins develops from one and the same ovum which, after fertilization, forms one zygote. The zygote undergoes cleavage and forms a blastocyst. At this time, due to some circumstances not yet properly understood, the embryonic mass of cells of the blastocyst becomes divided into two. The two parts separate and each of them develops into a complete body. The developing twins share the same placenta but

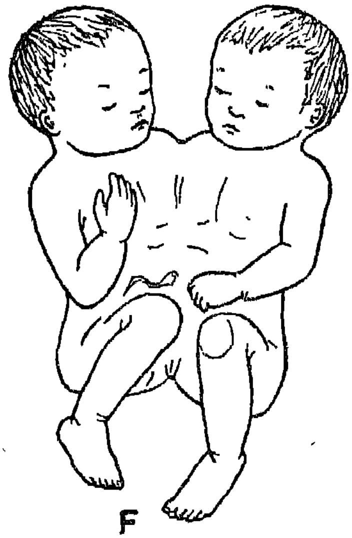
are attached to it separately (Fig. 21.8). These twins are called *monozygotic* be-

D

cause both develop by the splitting of a blastocyst formed from one zygote. Since

E

twins of this type are formed from a single zygote, the genetical constitution of both is exactly similar. This is the reason why monozygotic twins are always of the same sex, boys or girls, and are identical in all



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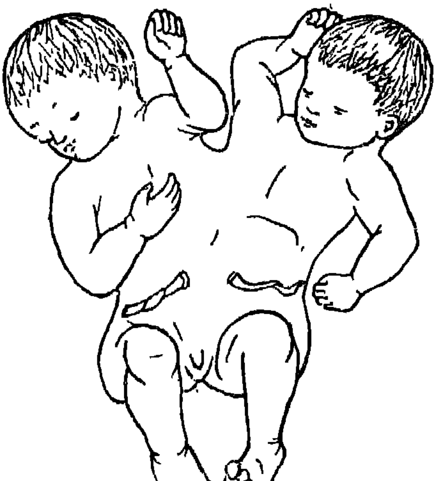
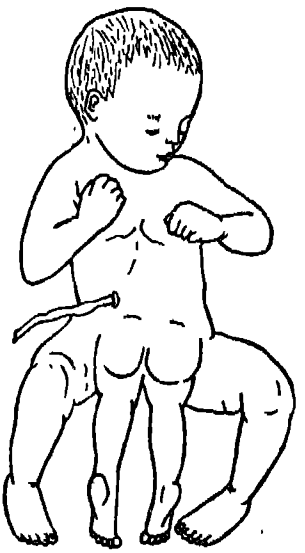
other respects as well, including appearance, height and even behaviour, etc. They are, therefore, known as identical twins also.





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Dizygotic twins

These twins may or may not be of the same sex. In their appearance, behaviour, etc., they art not identical but may differ

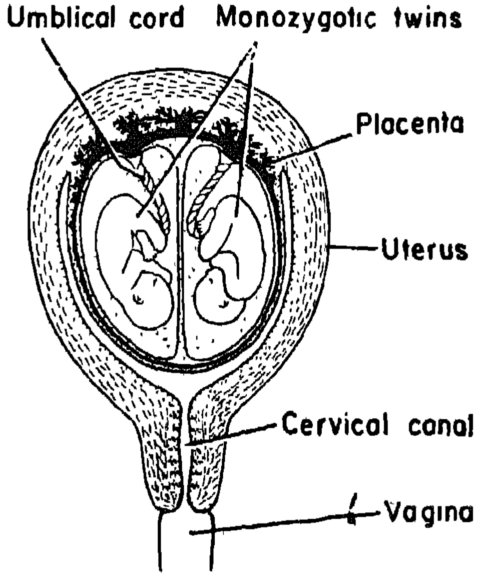

Fig. 21 8 Developing fetuses of *monozygotic* or identical twins.

from, or resemble, each other just like normal brothers and sisters born of the same parents but at different times. Such

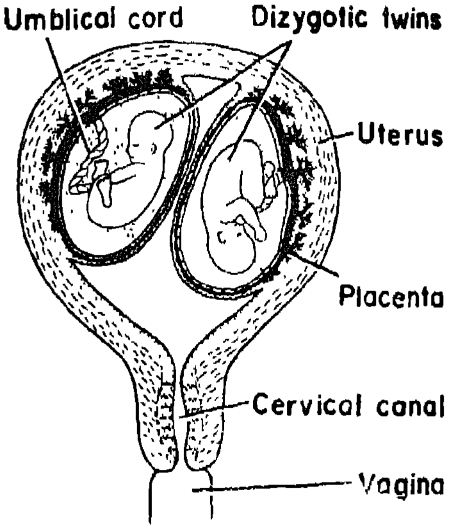

Fig. 21.9 Developing fetuses of *dizygotic* or fraternal twins.

twins are called fraternal twins. It so happens that sometimes the mother produces two ova, instead of the usual one at one time. Both ova reach the fallopian tube and are fertilized separately to form two zygotes. Each of the two zygotes then develops into a complete individual. The fraternal twins thus develop from two different zygotes and are, therefore, called *dizygotic twins* (Fig. 21 9). Since they originate from different zygotes, they differ in their genetic constitution. Therefore, they may or may not be of the same sex, and may differ from, or resemble, each other like usual brothers and sisters. Most of the multiple births involving twins, triplets, quadruplets, etc., are of the dizygotic type, each individual developing from a separate zygote.

Free martins

We have mentioned before that the

occurrence of dizygotic twins is not very uncommon in cattle. It has been found that sometimes the placentae of the two dizygotic twins connecting them with the uterus become fused with each other. As a result of this, a blood vascular connection is established between the two developing fetuses and the blood of one mixes with that of the other. If the twins are dizygotic, one fetus may be male and the other female. In such a case, some substance from the male fetus reaches the female fetus and prevents the development of the ovaries, oviducts and uterus of the latter. The sexual development of the female fetus is thus impaired and it becomes somewhat male-like and remains sterile (Fig. 21.10).

Such a female is called *free martin*. Free martin condition is found in cows, sheep, goats and pigs. In cattle, free martins develop in 11 out of 12 cases in which a female fetus develops as a dizygotic twin with a male fetus.

It has been known for long that if the twins in cattle are of separate sexes, the female is male-like and sterile The development of such twins, however, was rediscovered and described by Lillie in 1917. According to Lillie, the dominant hormone of the male fetus suppresses the hormone of the female fetus, preventing the sexual development of the latter and making it partly male-like.

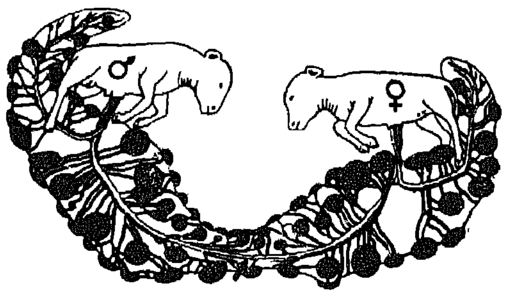

Fig. 21.10 Development of *free martin* condition in the female member of the twins in cattle is due to the fusion of placental blood vessels of the male and female fetuses. The arrow indicates where the fusion has occurred.

EXERCISES

1. Explain: (1) Mongolism, (2) Multiple births, and (3) Inborn errors of metabolism with an example,
2. Define Teratology. List six birth defects in human children caused by abnormal development during embryogenesis.
3. Explain :
   (1) Why women should avoid exposure to X-rays during pregnancy.
   (2) Why pregnancy women should be extra careful in taking drugs.
   (3) Why the diet of pregnant women should not be deficient in vitamins A, B and D.
4. What are the three causes of developmental abnormalities during embryogenesis ? Write a paragraph on each.
5. Define identical and fraternal twins. Explain how they are developed in human beings.
6. Write short notes on: (1) Conjoined twins, (2) Free martins.

CHAPTER 22

Cancer

MALIGNANCY or cancer is a form of abnormal development which occurs during adult life and transforms normal cells into cancerous cells. Cancer is a tumor which means an unusual amount of growth or enlargement of a tissue due to unlimited and uncontrolled repeated divisions of some cells. This kind of development occurs usually after the age of 35-40 years but it may also occur at a younger age. Generally, the cancerous tumor passes through a latent period of somewhat slow growth when the symptoms are not very obvious. Rapid growth occurs later, usually after the age of 50, and most often leads to the death of the individual.

Tumors can develop anywhere on the surface or in the interior of the body. Not all tumors are, however, cancerous. Two general types of tumors are recognised: (i) benign or non-malignant, and (ii) cancerous or malignant

A *benign (non-malignant) tumor* grows slowly but it may become quite large. It remains restricted to the place of its origin and does not spread to other areas of the body. It does not give rise to cancer. Most tumors are of this type.

A *cancerous (malignant) tumor* also begins as a small growth at first, for example, a pigmented mole somewhere on the body or a small swelling on the breast. It may grow slowly at first and more rapidly later. The tumor ultimately starts spreading to the neighbouring tissues like the roots of a tree The last stage comes when the cells of the tumor break away from it and migrate through the blood stream or lymph to the other parts of the body. There they accumulate and form secondary tumorous growths. This stage, called *metastasia*, is fatal and causes death of the individual sooner or later.

Cancer-causing Agents

Although it is still not clear as to how cancer is caused, several factors are now known which are cancer-producing or *carcinogenic*. They are listed as follows:

(1) Chronic physical irritation of a tissue may cause cancer. For example, during winter the Kashmiris keep a pot containing burning coal *(kangri)* against the abdomen under their dress to keep themselves warm This continuously irritates the abdominal skin and it is suggested that perhaps this may be the cause of greater frequency of abdominal skin cancer among the

Kashmiris. Betel (pan) and tobacco chewing is a common habit all over India and irritation to the buccal epithelium due to this may

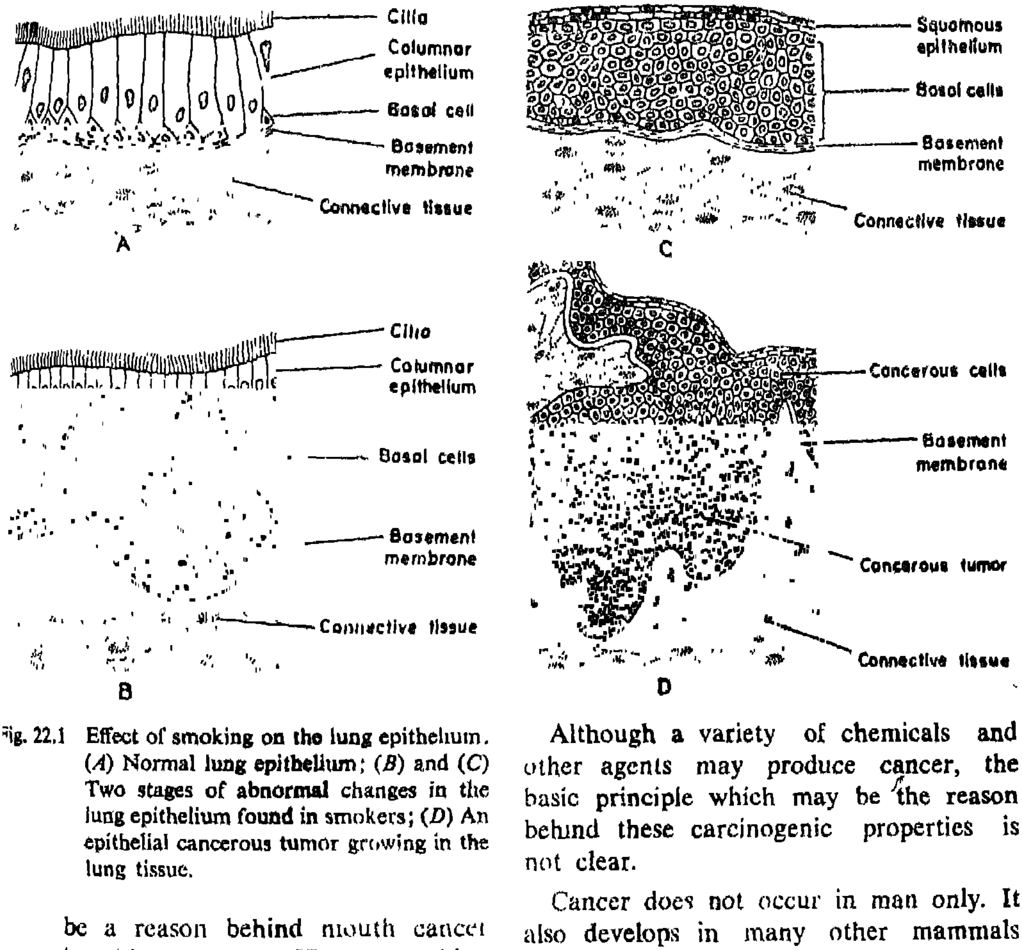

Fig. 22.1 Effect of smoking on the lung epithelium. (*A*) Normal lung epithelium; (*B*) and (*C*) Two stages of abnormal changes in the lung epithelium found in smokers; (*D*) An epithelial cancerous tumor growing in the lung tissue.

be a reason behind mouth cancer in this country. Heavy smoking irritates the lungs and is said to be associated with lung cancer (Fig. 22.1 A-D).

(2) A number of chemicals are known to induce cancer. These carcinogenic substances include nicotine, caffeine, products of combustion of coal and oil, several polycyclic hydrocarbons, etc., and some sex hormones and steroids if given or produced in large amounts.

(3) X-rays, ultra-violet rays and other ionizing radiations

(4) Viruses

Although a variety of chemicals and other agents may produce cancer, the basic principle which may be the reason behind these carcinogenic properties is not clear.

Cancer does not occur in man only. It also develops in many other mammals and lower vertebrates, and even in insects. Cancerous growths also occur in plants but in them they are caused by bacterial infections which have not been found to cause cancer in animals.

Basic Features of the Cancer Cells

Any cell of any tissue capable of mitotic division can become cancerous. The cancer cells are distinguished from the normal cells in several respects, such as

uncontrolled mitotic divisions and changes in the structure and metabolic machinery of the cells.

Growth by cell division is a normal feature of development and it occurs in most tissues throughout life. This is the mechanism by which an organism continuously replaces old worn-out cells by new ones to maintain its tissues in a working condition. However, normal development is organised growth. At some stage cell division stops and the cell enters the phase of differentiation. This control of cell division is true for all tissues and is a characteristic of normal development during the embryonic as well as post-embryonic periods of life. We do not know clearly as yet what factor or factors regulate cell division but that it happens so is an established fact.

The property and manner of cell division is the same for the cancer cells as for the normal cells. The cancer cells may divide at the same, slower or faster rate than the normal cells. However, the cancer cells continue to divide unchecked, resulting in an ever-increasing number of cancerous cells and, therefore, the size of the tumor keeps growing. The continuously produced daughter cancerous cells never differentiate and ultimately start invading the neighbouring areas. These cells finally break away from the primary tumor to migrate to other regions where also their divisions continue and secondary tumors are formed. *Cancer may, therefore, be defined as unorganized growth in which the controlling and regulating mechanisms have disappeared or have become ineffective.*

Two hypotheses have been proposed to explain how a normal cell changes into a cancerous cell:

(a) According to one hypothesis, cancer may be essentially due to alterations in one or more chromosomes or gene mutations in the nuclei of the sometic cells.

(b) According to the other hypothesis, a genetic change may not be an essential factor. Instead, some change occurs in the cytoplasm, resulting in the loss of control on the nuclear and cytoplasmic divisions.

EXERCISES

1. Define (1) Carcinogenic, (2) Benign tumor, (3) Cancerous tumor, (4) Malignancy or Cancer.
2. Explain:
   (1) Why heavy smoking is injurious to health.
   (2) Why there is greater frequency of abdominal skin cancer among the Kashmiris
   (3) Why the habit of chewing *pan* and tobacco is harmful
3. Name the various carcinogenic factors
4. What is the basic characteristic of the cancerous cells which distinguishes them from the normal cells ?
5. What are the hypotheses to explain how a normal cell changes into a cancerous cell ?

CHAPTER 23

Regeneration

WE HAVE pointed out earlier that development does not end with the completion of embryogenesis. Developmental potentialities persist into the post-embryonic life more or less in all organisms. These enable them to replace or repair the lost or damaged structures during their larval and adult life. In the course of its life, an organism constantly loses many kinds of cells and other structures due to normal wear and tear and these need continuous replacement. The body may suffer damage of one kind or the other which may be a simple superficial wound or it may cause partial or severe destruction of some tissues. The damage may be even more extensive involving the loss of part or whole of an organ or even a large portion of the body. If you cut off part of the tail of a frog tadpole or a house wall-lizard, the missing part is developed again from the remaining portion of the tail. This restoration of the removed part of the tail is regeneration.

Regeneration is defined as replacement, repair or restoration of the lost or damaged structures or reconstitution of a whole body from a small fragment of it during the post-embryonic life of an organism.

The ability to regenerate the lost structures is present in all animals at least to some extent. However, there are many differences among different animals with regard to what and how much can be regenerated. In some, almost anything lost or damaged can be regenerated, while in others this power is limited.

Various animals differ a great deal in the capacity of reparative regeneration in their post-embryonic life.

Among the invertebrates, *earthworms* and several other *annelids* are able to regenerate some segments removed from the anterior and posterior ends of the body. Some *mollusks* are able to regenerate eye stalks, eyes, parts of head and foot. Limbs are regenerated in many *arthropodes*, including some insects, *crustaceans* and *spiders*. Arms are rapidly regenerated by *starfishes* and several other *echinoderms*. The phenomenon of *anatomy* occurs in holothurian echinoderms. This consists of these animals throwing off their entire internal viscera, when in danger, and then regenerating them.

Among the vertebrates, the most extensive power of organ regeneration is found in *urodele amphibians* like *salamanders*, *Axolotl*, etc. They can regenerate limbs, tail, jaws, intestine, external gills and re-

tina throughout life. Some of them can also regenerate lens of the eye Among the

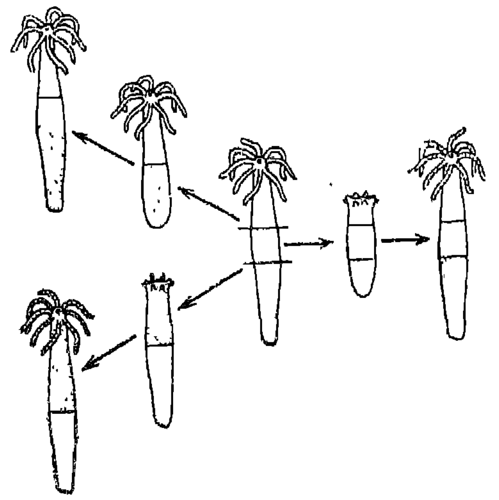

Fig. 23.1 Regeneration in *Hydra*.

anuran amphibians like frogs and *toads*, tail is regenerated in the tadpole, and also the hind limbs if the tadpole is quite young when the limb is amputated. The power of limb regeneration is absent in the adults of most anurans. Tail regeneration also occurs in the *ammocoeta larva of lampreys* and in some *lizards*. Lizards also practise autotomy and leave their tail behind it attacked by an enemy and then regenerate it. In some *fishes* and *birds*, some regeneration of parts of fins and beaks, respectively, is known to take place

No external parts are regenerated in *mammals* but these animals have great capacity to regenerate the liver If part of the liver is removed, the remaining portion grows by repeated division of its cells until the original volume of the liver tissue is attained. However, the normal shape of the liver is not restored. Similarly, if one kidney is removed, the other enlarges to take over the function of the missing kidney also. This type of reparative regeneration is called *compensatory hypertrophy*. It is different from the regeneration, for example, of a frog tadpole limb in which the regenerated part resembles the removed part exactly in shape as well as in function

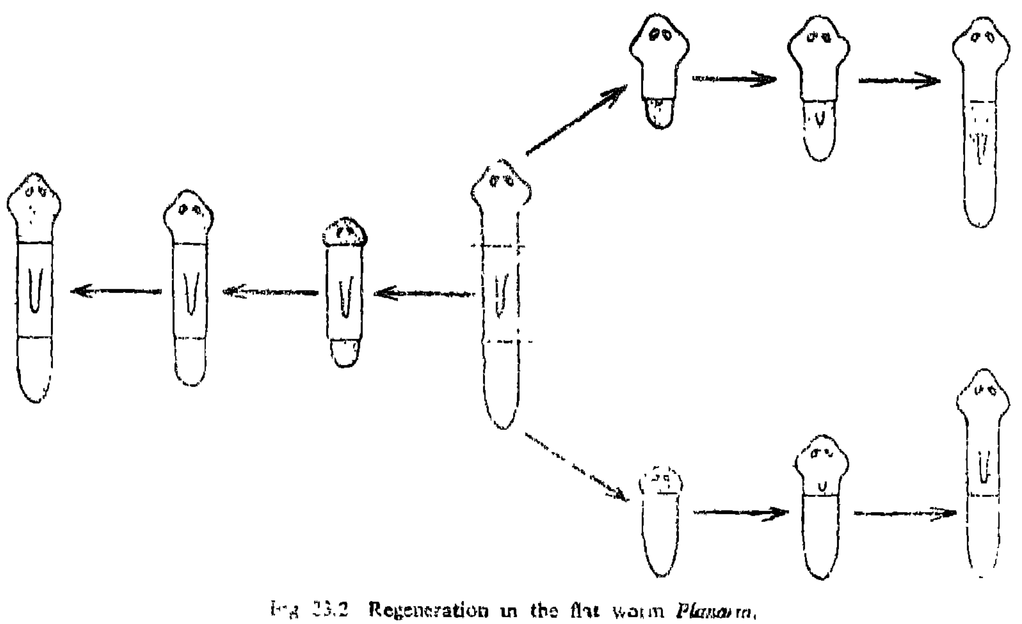

Fig 23.2 Regeneration in the flat worm *Planaria*.

The ability to regenerate the entire organism from a small, isolated fragment of its original body is found in a very few groups of animals including sponges, some coelentrates, flat worms, nemertean worms and some ascidians. The ability of the *Hydra* to regenerate was first discovered by *Trembley* as long ago as 1742. If you cut a *Hydra* or *Planaria* (flat worm) transversely into two or several parts, each of them develops into a complete organism (Figs. 23.1, 23.2). Fragmentation and regeneration are the usual forms of asexual reproduction in several of these animals.

In many ways, the process of regeneration is similar to the process of embryonic development. As in the latter, regeneration involves cell division, cell movements, cell and tissue differentiation and development of form or morphogenesis. However, for regeneration cells arise through a process of de-differentiation from the already differentiated and specialized cells of well-formed tissues. Moreover, regeneration occurs in a functioning adult or larval body and the hormonal and neural factors present in the body not only influence, but are also necessary for regeneration to occur.

EXERCISES

1. Define regeneration. Enumerate the similarities and differences between the developmental process which occurs during regeneration and embryogenesis.
2. Write briefly on distribution of the capacity of regeneration in various animals.
3. Write short notes on :
   (1) De-differentiation
   (2) Blastema
   (3) Compensatory hypertrophy
   (4) Autotomy

CHAPTER 24

Aging

THE AVERAGE life span differs very widely for different organisms While some live for only short periods, others may have a life of several decades or even centuries. None, however, lives forever. Even if an individual meets no fatal accident, is not eaten up by a predator, or does not suffer a killing disease, death still comes as the natural final result of old age. As an organism grows older, its powers of metabolism gradually decline and its capacity to replace the worn-out cells and to repair the damaged parts decreases. The cells, tissues and organs gradually become weak to perform their functions effectively or to resist infections from outside. Ultimately, some vital organ, for example, the heart, the kidneys, the brain or the liver, etc., stops functioning altogether, resulting in the death of all other parts of the body and of the organism as such. These changes appearing with advancing age are known as aging. They occur in all organisms and ultimately lead to their death.

Aging is defined as the process of progressive deterioration in the structure and function of the cells, tissues and organs of the organism as it grows older. The area of developmental biology which is concerned with the study of the processes of aging is known as *gerontology*.

Signs of aging

We are all familiar with the symptoms of aging in man, some of which we may mention here as illustrative examples. As compared to a 30-year old person, in a man of 70 years the heart pumps only 65 per cent blood per minute and the blood going to the brain and the kidneys is reduced to 80 per cent and 42 per cent, respectively. At the age of 20, blood takes about four litres of oxygen from the lungs per minute, but in a 75 year old man it takes only about 1.5 litres of oxygen in the same amount of time. With age, the number of kidney tubles is reduced to about half and that of taste buds in the tongue to about one-third the number found in a young man. Production of new erythrocytes from the bone marrow declines, cells gradually lose the capacity to retain water, blood volume decreases, and tissues become drier. The result is the old man with dry and wrinkled skin, flabby and weak muscles, brittle bones, reduced blood circulation, decreased formation of urine and a thin, shrivelled and stooping body. Similar changes occur in other animals also as they grow in age.

The outward signs of aging are obvious and are easy to find out However, these symptoms are the result of changes taking place within the cells and outside in the inter-cellular spaces in the tissues of the body and these are not so easy to discover. A number of cellular and extra-cellular changes have been observed in different tissues of several animals as they grow old.

Cellular changes

These include chromosomal aberrations and gene mutations in the nuclei of body cells (somatic mutations) which must disturb the DNA structure Defects in chromosomes, for example, have been found to increase with age in the liver cells of mice, dogs and man. In the liver cells of mice, it has been found that the enzyme *aldolase* becomes more and more inactive with the increasing age of the animal. At the same time, the cells of older animals are found to contain greater quantities of defective proteins. Large quantities of a pigment are found to accumulate in the cells of aged animals, especially in the tissues whose cells stop dividing early such as the brain and muscles. This pigment perhaps represents the remains of old worn-out organelles such as mitochondria.

That cells do age is also shown by recent studies of human cells cultured *in vitro:* It is found that the cells taken from the lungs of a human fetus divide only about 50 times and then they lose their vigour and die. The cells taken from older individuals are able to divide a lesser number of times. However, different cell types stop dividing at different times and they also seem to undergo age-related changes at different rates.

Extra-cellular changes

Inter-cellular spaces in all tissues are filled up by various materials secreted by cells, such as polysacchrides, and fibrous proteins, including collagen and elastin The most prevalent among these materials is *collagen* which constitutes about 40 per cent of the total protein content of the body. For age-related changes, collagen has been studied the most, and several of its properties suggest that it may be significantly involved in the process of aging of the cells and the body in general.

Young collagen is permeable, flexible and easily soluble. With age, however, it becomes less permeable, rigid and insoluble which should be very harmful for the cells. Due to these changes in the surrounding collagen, it should be more and more difficult for the nutrients and oxygen to diffuse into the cells and for the nitrogenous waste and carbon dioxide to pass out of them The reduction in the diffusion of materials into and out of the cells due to a mechanical obstruction caused by aged collagen may result in the deterioration and aging of the cells of various tissues, including those of the vital organs

Theories of aging

Why should an animal age at all? Why do some animals age more rapidly and have shorter life span than others? Why do different cell types and tissues within the same individual age at different rates? What are the primary causes of deterioration in the body as the animal grows older? We still do not know enough about the process of and the changes during aging. Much more investigation and research is needed in the field of gerontology to find satisfactory answers to these and such other questions.

Meanwhile, many theories have been proposed to explain the phenomenon of aging.

Some biologists suggest that adverse changes in the environment are the causes of aging in the organisms Others believe

that aging is an intrinsic genetic property of the cells of an organism According to a compromise theory, aging is due to an interaction between hereditary factors (genes) and the environment. We know, for example, that domestication of animals increases their life span. Another theory proposes that the cells and organisms with a high rate of metabolism age more rapidly and die sooner than those with a relatively lower rate of metabolic activity.

A more recently proposed *immunity theory of aging* suggests that the decline and disappearance of the thymus gland by late middle age in man is the primary cause of aging. With the disappearance of this gland, the defences of the body against foreign invasion of germs, etc., weaken and, at the same time, the number of defective, abnormal and harmful cells produced in the body itself goes up which results in the increasing damage and destruction of the tissues.

According to still another theory, the primary defects due to aging may appear in certain centres of the central nervous system which stimulate and regulate the activity of the endocrine glands. In the absence of proper guidance from the brain, these glands do not function properly. Reduction in the hormones leads to the defective functioning and aging of the cells of many tissues and organs. It is known, for example, that reduction of the sex hormones produces symptoms of aging in many mammals, including man.

While each theory of aging is supported by some evidence, none of them explains this phenomenon in all cases. A comprehensive theory to explain aging in all kinds of cells and organisms can be formulated only when more facts are known about aging processes in a variety of species living under different conditions

EXERCISES

1. Define aging and gerontology. What are the symptoms of aging in man ?
2. What are the cellular and extra-cellular changes related to the process of aging ?
3. Describe the various theories proposed to explain aging.
4. How may the thymus gland, the central nervous system and the hormones be associated with aging ?

UNIT 3

BIOLOGY AND HUMAN WELFARE

CHAPTER 25

Domestication of Plants by Man

IN THE history of human civilization, the earliest stages in crop cultivation are believed to be linked with the settling of man in different areas which followed his nomadic life. The earliest sites where societies started growing were around the Nile in Egypt, the Chinese river valleys and the northern Indian plains. These were fertile areas with plenty of water which best suited the requirements of crop-culture. The bountiful agricultural production in these areas made people self-sufficient and enabled them to build great civilizations, the remnants of which still stand.

While man's knowledge of wild plants as the sources of food could be as old as his hunting habits, the earliest traces of human civilization which gave clear relationship between crops like wheat, barley and rice are found in the Indus Valley (now in Pakistan). The historians put the age of these civilizations to about five to six thousand years from now. It can easily be presumed that the skills of agriculture must have been developed by man still several thousand years back. The Aryan tribes drifting from the Central Asia region which later invaded this civilization also knew the skills of agriculture—the use of bullocks and plough—and were able to manage their cattle. They later spread themselves, numerically and culturally, all over the north Indian plains and further up to the extreme south.

Agrarian society of a distinct type got established throughout the country. The villagers cultivated the land which belonged to the kings, and later to the zamindars or other land-owners, and provided them with revenues which supported the states and officials. Smaller land tenancies were later established in return for various services to the rulers or the village chiefs by carpenters, weavers, blacksmiths, etc. This became an established system of sharing of resources and division of labour in the society which was stable enough to withstand invasions, changes of dynasties and other social forces.

But the rate of increase in population after 1921 started putting an increasing demand on the food supply. The phase between 1921 and 1951 showed the average annual rate of increase in population of about 1.3 to 1.4 per cent coupled with a decrease in the average per hectare yield of foodgrains such as wheat and rice. The production of wheat averaged around 798 kg/hectare in 1901 but only 645 kg/hectare in 1952. Similarly, the figures for rice were 1058 kg/

hectare in 1901 but only 800 kg/hectare in 1952

Concerted efforts are being made in our country to minimize the increasing disparities between the number of people to feed and the food produced to meet their demands. While the population is still increasing at a devastating rate, the country has been able to achieve self-sufficiency in food for the last couple of years.

In 1952, the yield per hectare of wheat and rice stood at 645 kg and 800 kg, respectively. The corresponding current figure can be placed approximately at 1400 and 1800 kg/hectare for wheat and rice, respectively. While fluctuations in yield per acre have been noted, since the early seventies, due to the vagaries of weather conditions, there is still a great deal of scope for increase in food production For this the area under irrigated cultivation has been increased with more intensive cultivation that has marked the "green revolution" in many parts of the country. The important factors contributing to the green revolution have been (i) development and introduction of high-yielding varieties of crops, (ii) extension of the high-yielding varieties over larger areas in the country, (iii) multiple cropping, using high inputs of water and fertilizers which provide economical yield of two to three crops in a year from the same field, (iv) use of crop protection measures against diseases and pests, and (v) transfer of the technology of scientific farming from research farms to village farmers.

The green revolution has enabled us to have the following projection for the immediate future in regard to various crops in our country.

The recent breakthrough in agriculture is bringing about significant changes in the traditional organizational patterns in villages presented earlier. The village is hardly a self-contained unit with the traditional relationship between the land-owners, the tillers, the money-lenders and the local artisans. It is now getting increasingly linked with the rest of the world through the inputs it requires in terms of materials, knowledge, and skills and through the outputs of production to other areas. The transport of inputs and outputs, coupled with the storage and distribution of the surplus, has created a need for better infrastructure of roads, godowns, repair facilities and the like.

TABLE 26.1*

The projected figures for area, yield and production for the year 1980-81, with the year 1968-69 as the base

	1968-69			1980-81		
	Area (in million hectares)	*Yield (kg/hectare)*	*Production (in million tonnes)*	*Area (in million hectares)*	*Yield (kg/hectare)*	*Production (in million tonnes)*
Cereals	99.2	843	83.6	107.00	1389	148.6
Pulses	21.3	488	10.4	25.0	44	18.6
Oilseeds	14.6	473	6.9	20.0	760	15.2
Sugarcane (Gur equivalent)	2.5	4876	12.0	3.2	6875	22.0
Cotton (Lint)	7.7	124	0.85	11.5	172	1.98

*From *Our Agriculture*, NCERT, New Delhi.

The rural scene is undergoing a change and the isolation of the farmer in terms of money market has been broken. Nationalized banks have moved into the rural areas. The farmer is getting integrated with the external world on an ever-increasing scale.

The story of man's domestication of plants has reached such a stage in India that even in the seventies agriculture dominates the national economy. It provides employment to nearly three-quarters of our population and accounts for nearly half of the national income. Our recent successes in agriculture may prove illusive if we become complacent. National efforts to feed the additional 1.5 million people every year must continue with full vigour along the following lines for the immediate future.

"1. Full exploitation of high-yielding varieties of cereals with greater attention to qualitative aspects.

2. Intensive effort in selected areas to raise the yield levels of major commercial crops.

3. Continued expansion of irrigation facilities and reorientation of current irrigation practices.

4. Expansion in the supply of fertilizers, plant protection materials, farm machinery and credit.

5. Improvement in the agricultural marketing system in the interests of the producer, and assurance of minimum prices for major agricultural commodities." *

However, for the more distant food needs of man another dimension has also to be borne in mind. Of nearly 360,000 plant species known so far only a handful are used as food sources, of which only a dozen provide nearly 90 per cent of the global food supply. We must explore if many more could be added to this list. We need to work out a strategy for the arid parts of the globe. These account for about a third of the earth's habitable area. Only about 150 million people inhabit these areas at present. Many more could be supported and their quality of living improved if we can transform them into green fields. The key lies in the field of proper water-management technology through collaborative global efforts.

The phytoplankton of the sea is many times greater a producer of organic matter on the earth than all the land plants put together. Man consumes only the fishes and other marine animals which feed upon these planktons. Much greater quantity of food could be available to us if we could develop a suitable processing technology to this end. But with the seas getting increasingly polluted in the recent times, more concerted research and action plan would be necessitated to achieve a breakthrough.

Man has still a long way to go in his venture to domesticate plants for his ever-growing needs. The potentialities are enormous.

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* From *Our Agriculture*, NCERT, New Delhi

EXERCISES

1. Explain how the domestication of plants is related to the early development of different civilizations.

2. How do our present agricultural communities contrast with those of the last century or earlier ?
3. Describe the significant changes in food production in relation to population growth since the beginning of the present century.
4. List various components of the "green revolution" in India.
5. Present a critical appraisal of the suggested strategy to meet the short-term and long-term food requirements of man.

CHAPTER 26

Important Cultivated Crops

OVER 70 per cent of the cultivated area in our country is under foodgrains which include cereals, millets and pulses. The word 'cereals' finds its origin in 'Ceres', the greek goddess of grains.

The cereals which belong to the single family, Graminae, provide by far the most important staple food for man. The cereal grain is a fruit in which the dry ovary wall is fused with the seed coat of the single seed contained in it. The storage products in the grains are chiefly carbohydrates (predominantly starch), some proteins, and scanty amounts of lipids, vitamins and minerals.

Cereals are annual herbs with cylindrical stems. The internodes are mostly hollow with solid nodes joining them. In addition to other vegetative features they are characterized by their typical inflorescence, i.e., spikelet which bears several sessile flowers. Inflorescence in cereals is commonly referred to as 'ears', the emergence of which marks the end of the apical growth.

Cereals have been widely investigated in regard to their cultivation practices such as irrigation, manuring, tillage; improvement aspects such as selection, hybridization, mutation; physiological aspects such as nutrient requirements, photosensitivity, photosynthetic efficiency and yield determining factors; and in regard to their diseases and pests.

Cereals

The agronomic aspects of rice and wheat, the two most important cereals of the world, are given below.

Rice

Rice (*Oryza sativa*) has the highest acreage of all the cereals in India and is cultivated in 39.67 million hectares. The current annual production is of the tune of 75 million tonnes of paddy. More than half of the country's population consumes rice as the principal staple diet. It is the most favoured food in Asia, the continent which provides the wet and humid climate which is the best suited for the crop. Even the drier areas like the plains of the Punjab have taken up rice farming at a substantial level with the expansion of the irrigation system.

While rice is grown in nearly all parts of the country, the states of Uttar Pradesh, Bihar, West Bengal and Assam account for nearly three-quarters of the total acreage under rice in India. In all parts of the country a number of high-yielding new

varieties like *Cauvery*, *T-141*, *Padma*, *Jaya*, *Pankaj*, *Sabarmati*, *IR-8* and *Jagannath* have been introduced. Some of these are short-duration dwarf varieties with very high yield potentials which, if backed by intensified efforts (including the provision of fertilizers and irrigation), can substantially increase our annual rice production.

Although rice can be grown in a variety of soil types, the most suitable one is the clay-loam and the least desirable type is the soil rich in larger particles. For the most part of the life history of the plants, the soil is kept in water-logged conditions. The rice plant thus qualifies as a semi-aquatic plant.

There are three seasons for Rice cultivation-rainy season, winter and summer In north India, rice is grown during rainy and summer seasons while in south India, It is grown in the winter The recent trend is to recommend different varieties for different seasons and different types of field conditions. The seeds are either directly broadcast or raised as seedlings which are later transplanted in water-logged fields. Thorough preparation of the field involves ploughing, flooding and cross-ploughing.

The intensive cultivation of rice, besides involves the addition of large amounts of fertilizers and manures, coupled with suitable plant protection measures as the umbrella against the incidence of diseases and pest-infections.

Sowing and harvesting are done manually, but for threshing machines are being increasingly employed

Wheat

Wheat (*Triticum vulgare*) is only next to rice, among the cereals, in regard to the area and production in the country. It occupies 20.1 million hectares and the production is 28.3 million tonnes. Wheat production has nearly quadrupled in about a decade's time in India. The states of Uttar Pradesh, Punjab, Rajasthan, Madhya Pradesh and Haryana are the major wheat producers. Besides, Bihar, Maharashtra and Karnataka also produce wheat in significant amounts. The wheat revolution, the most dominant component of the green revolution, has been due to the introduction of disease-resistant, fertilizer-responsive, strong-strawed and dwarf varieties. The parent stock of these was imported from Mexico.

A number of varieties suited to the Indian climate and tastes have been developed through mutation and hybridization in our country. The total wheat production can be further increased through the introduction of the technology of intensive cultivation over the other regions of the country. Our present area under irrigation is a major constraint at the moment.

There are numerous new varieties of wheat Some of these are: *Kalyan Sona*, *Sonalika*, *Sherbati Sonora*, *Hira*, *UP 301*, *RR-21*, *UP 308* and *Moti*.

Wheat is grown in both irrigated and unirrigated areas but the average yield in the latter situation is much lower. The main growing season in the northern plains is from October to March for the *Rabi* crop. It takes around four to five months to mature and its cultivation is squeezed between the rainy and the hot summer season. In the non-irrigated conditions, a shower or two in the winter makes a significant difference in the crop yield. If irrigation facilities are available, generally 4—6 irrigations are regarded as ideal for the optimal yield. The new high-yielding dwarf varieties require much greater inputs of chemical fertilizers and water than the *Desi* varieties.

Millets

Jowar (*Sorghum vulgare*), Bajra or Pearl millet (*Pennisetum typhoides*) and Ragi or Finger millet (*Eleusine acoracana*) are the chief Indian millets. Jowar occupies the

first place amongst these with 16.0 million hectares under its cultivation, giving an annual yield of 9.5 million tonnes. Bajra or the Pearl millet occupies an area of 11 6 million hectares. The annual production is to the tune of 5.8 million tonnes Ragi or the Finger millet occupied 2.6 million hectares in 1977 and produced 2 6 million tonnes The state of Karnataka alone produced 30 per cent of this total while the rest came from Tamil Nadu Maharashtra, Andhra Pradesh, Bihar and Uttar Pradesh. Bajra is a crop of the dry parts of the country, grown mostly in the states of Rajasthan, Gujarat, Maharashtra, Haryana and Uttar Pradesh. *HB 1*, *HB 3* and *HB 4* are some of the recent high-yielding varieties. Jowar is also an important crop of the drier parts of the country and most of it is grown under unirrigated condition. *CHS 1*, *CHS 2* and *Swarna* are some of the high-yielding hybrid varieties.

Millets are used as food, animal feed or fodder. As a foodgrain, they are not very popular among the city dwellers and are preferred only after wheat and rice even in the villages. Ragi is particularly processed for infant food, since it is quite nutritious.

Pulses

Pulses constitute the important protein source in our diet. They are leguminous crops grown largely on unirrigated lands. They are also grown between two cereal crops, since the pulses have root nodules which enrich the soil by fixing the atmospheric nitrogen. For this reason they are often not manured. *Arhar* (*Cajanus cajan*), *Chana* or Bengal gram (*Cicer arietinum*), *Urad* or Black gram (*Phaseolus mungo*), *Mung* or Green gram (*Phaseolus aureus*), Lentils or *Massoor* (*Lens esculenta*) are the important pulses in our diet. Recently, there has been a great deal of emphasis on the cultivation of Soyabean (*Glycine max*) as a source of high quality protein and oil.

Gram

Bengal gram is the most important amongst the pulses of India. It is cultivated throughout the country but nearly 80 per cent of the area under cultivation lies in the northern zone. Black cotton soil (rich in clay) is ideally suited for this crop It is sometimes grown on clayey loams, but rarely on other types of soils. It is sown during October to December as the *Rabi* crop (after the rainy season) and makes use of the moisture that remains stored in the soil. While it is grown mostly under dry conditions, irrigation substantially increases the crop yield. The yield varies between 600 kg/hectare to 1600 kg/hectare.

The plants are small (30—59 cm tall) shrubs which are extensively branched. The leaves are pinnately compound and are of bluish-green colour. The flowers are solitary, borne in the axils of leaves (for botanical details,see family leguminosae, in Unit on Systematics in Part I).

Many distinct varieties are known, based on the features of the seed which could be yellow, green-black or brown on maturity. The seeds are eaten fried or boiled. They are also ground to give flour which is taken as such or in a variety of sweetish or saltish preparations in different parts of the country. It is also used as horse-feed.

Oilseeds

Oilseeds occupy about ten per cent of the total cropped area in our country, but a very small fraction of this area is under irrigation. Oilseed crops are often grown along with other crops in a mixed form. The country has been falling short of the production of oilseeds *vis-a-vis* our annual requirements.

Safflower (*Carthamus tinctorius*), Cottonseed (*Gossypium herbaceum*), Groundnut (*Arachis hypogea*), Sesame (*Sesamum indicum*), Coconut (*Cocos nucifera*) and, very recently, Sunflower (*Helianthus annus*), along

with those of the Brassica family (*Brassica campestris*), are the most important of the oilseeds which are used for oil extraction for human consumption in India

Groundnut

It is predominantly a tropical crop but its cultivation extends to sub-tropics and even to the cooler parts of the world with a long enough summer to permit its maturity. In India, this crop is grown all around, the important centres being Tamil Nadu and Maharashtra. It is grown both as a dry crop as well as an irrigated crop but the yield in the areas with less than 50 cm of rain and without irrigation is rather poor. A light sandy soil or sandy-loams are the suitable soil types for this crop but, lately, it is being grown on all types of soils. A number of early maturing varieties are under cultivation which take less than three months to mature. The plant, belonging to the sub-family papilionacae, is a low-growing, profusely branching, annual herb with a prostrate habit. The flowers (for floral details see family leguminosae in the Unit on Systematics in Part I) are borne on stalks close to the running stem, which after fertilization bend down and enter the soil where the pod grows and matures Upon maturity the whole plant is pulled out and the pods separated. The yield varies between 800 kg/hectare to 2000 kg/hectare of unhusked pods, depending upon the variety and the cultural conditions.

Fibre Crops

Cotton and jute, the two most important fibre crops, provide the raw materials for our textile and jute industries. These are largely grown in unirrigated conditions. The quality of the most of our cotton is suitable for coarse clothes only. For finer clothes, we import long staple cotton from other countries. Some new long staple type varieties developed in our country are *Sujata* and *Hybrid No. 4*. While cotton is a crop of the central parts of the country, jute is grown in the eastern states of Assam, West Bengal and Bihar. Intensive research is continuing for the development of high-yielding and fertilizer-responsive varieties of fibre crops in India.

Vegetable Crops

Vegetables are the chief source of minerals and vitamins in our diet but the per capita consumption of these items is much lower compared to many other countries of the world. In addition to providing minerals and vitamins, they also provide proteins and carbohydrates.

Various types of vegetables such as cauliflower, tomato, brinjal, green peas, cabbage, turnip, lettuce, green beans, *bhindi* (lady's finger), carrot, onion, spinach, various cucurbits and many others are grown very commonly in kitchen gardens around houses in all parts of the country. Besides, they are also grown on large plots like other field crops.

Vegetables belong to many diverse botanical families and differ greatly in their habits, mode of cultivation, season of cultivation, parts that are consumed, and perishability. While these descriptions are beyond the scope of the present account, one thing that is common amongst many of the vegetables is that greater per plant care is needed for them in contrast to the other grain crops.

Fruit Crops

Like vegetables, fresh fruits also contribute vitamins and minerals in our diet but, unlike the leafy or green vegetables, many of the fruits like banana, grapes and mangoes are rich sources of sugar and thus qualify as high-energy foods.

Fruit crops are mostly perennial trees like mango, guava, papaya, orange and other citrus fruits of the tropics and sub-tropics, and apples, apricot, peach, plum, grapes

and others of the cooler parts. Like vegetables, they grow around houses, as lines beside roads or in large commercial orchards. There is a variety of ways for processing and preserving fruit products for later use, such as juicing, canning, pickling, and drying, which are in vogue in different parts of the country

Mango

Mango (*Mangifera indica*) is one of the most popular fruit crops in the tropics and sub-tropics of many parts of the world. The fruits are borne in clusters and assume a variety of colour, flesh, taste and flavour upon ripening, depending upon the variety and the locality. Biennial bearing is a common phenomenon in mango. This means that each twig of a tree bears the apical cluster of flowers only once in two years. The vegetative growth of each twig alternates with its reproductive growth annually. But all branches or twigs may or may not synchronize each year for vegetative or reproductive growth. Stem grafting is an old common practice of vegetative and propagation in mango.

Banana

Banana (*Musa sapientum*) is an inexpensive fruit which belongs to the monocotyledonous family, Musaceae. It is a favourite of the tropics and rarely grows in temperate regions. The plants are characterized by the soft cylindrical aerial body consisting of leaf sheaths which bear a ring of leaves at the apex. The inflorescence arises in the centre of the cluster at the apex in which the flowers are borne in the axils of large bracts. The fruits generally develop parthenocarpically and, upon ripening, the skin could be yellow, green or red, depending upon the variety. The propagation is of vegetative type where young plants with the underground stem are transplanted.

Sugar Cane

Sugar cane (*Saccharum officinarum*) belonging to the family of grasses is the source of all sugar in our country India is supposed to be the centre of origin of this crop from where it spread to all parts of the world. It is mainly a tropical or sub-tropical crop but its cultivation sometimes extends beyond to the temperate parts also. In India, it is cultivated in more than two million hectares and the total production is higher than any single sugar cane farming country on the earth. The growing period of sugar cane varies from ten to eighteen months, but in India it is mostly grown as an annual crop, being harvested in the winter in the northern parts. It is easily damaged by frost. The ideal climate for sugar cane farming exists in the southern parts of the country but it is also extensively grown in the northern states of the Punjab, Haryana, Uttar Pradesh, Bihar and Orissa. The crop is vegetatively propagated. Stem cuttings with axillary buds are planted in rows to raise the crop. While irrigation greatly improves the yield, the sugar cane farming is still mostly under rain-fed conditions. The sugar yield is of the order of eight to ten per cent of the fresh weight of the stem.

EXERCISES

1. Give a brief account of the cereals as grown in our country.

2. What are the important Indian millets and under what conditions are they grown ?
3. How are pulses grown in India ? Why is it not very necessary to supply nitrogenous fertilizers to the pulse crops ?
4. Write briefly about the mode of propagation in Mango and Banana
5. Name some important oilseeds and describe briefly the cultivation of groundnut.
6 Name some improved varieties of rice, wheat, jowar, bajra and cotton.

CHAPTER 27

Plant Diseases

PLANT diseases have been known since the dawn of history. Reference to blight, mildew and rust occurs in the Bible, in the ancient writings of Greeks and Romans, but nobody knew or referred to the cause of such diseases. The ancient Romans believed two Gods, Robigues and Robigo, to be responsible for the cereal rust and planned an annual festival, the *Robigalia*, to appease these Gods. Ergotism caused in cattle grazing in infected fields was ascribed to the evil spirits prevailing there. It took a long time for the scientists to disprove these superstitious ideas.

Man knew that many diseases are contagious or infectious but the cause for the infection could not be known until Leeuwenhoek discovered a new unseen world in 1676 with his crude simple microscope. Leeuwenhoek was a linen merchant and lens grinding was his hobby. He reported the discovery of "little animals" (bacteria, yeast) to the Royal Society of London, and today he is regarded as the father of microbiology. Though microbes were discovered in the seventeenth century, it took almost 200 years to get a clear evidence that diseases are caused by various microorganisms. Interestingly enough, the evidence did not come from human or animal diseases, but grew out of the study of plant diseases. An Italian botanist, Micheli, observed the germination of fungal spores while a French mycologist, Tillet (1755), worked with the bunt of wheat, and Prevost (1807) showed a close relationship of fungus with its wheat host. Prevost particularly observed the germination of the spores and followed the penetration of the fungal hyphae within a young wheat plant. However, none of these observations received any serious attention.

In 1845, potato plants throughout North Europe were devasted by a disease called potato-blight that overnight turned the potato fields into black masses of rooting plants. Ireland, where potato was the staple food, was most affected. Nearly half a million Irish died during the following two years and this famine was recorded in history as 'The great Irish potato famine'. However, this famine may be considered as a blessing in disguise since it hastened the realization of the importance of plant diseases. Fortunately, good microscopes became available in the meanwhile and it was observed that the dying potato plants were full of fungal mycelia. The initial controversy whether the fungal mycelium was the cause or the result of the disease was

set at rest by M.J. Berkely and Heinrich Anton De Bary, British and German mycologists, respectively. In 1861, they identified the fungus as *Phytophthora infestans* and convincingly proved that the fungus was the cause and not the result of potato-blight This established the view that fungi caused plant diseases and thus an independent branch of science, namely plant pathology, was born.

During 1876-78, the contributions of the French chemist, Louis Pasteur, the young German country doctor, Robert Koch, and the British surgeon, Joseph Lister proved beyond doubt that diseases are caused by germs. Particularly, Koch's experiments led to the 'Koch postulates' which are followed even today to establish the causal relationship between a specific microorganism and the specific disease it causes whether in man, animal or plant.

What is a plant disease? How do we differentiate a 'diseased' plant from a healthy one ? A plant is considered healthy when all the physiological processes are in order with a coordinated functioning of all its organs and parts It is diseased when the physiological process is disturbed which usually manifests itself in morphological changes. Thus, a disease causes 'symptoms'. The diseased condition of a plant is also greatly influenced by physical environment, viz., the conditions of the soil, humidity, temperature and other factors. A healthy plant, on the contrary, maintains equilibrium between it and the environment.

Around 1870, downy-mildew of grapes threatened the vine orchards, and the wine industry of France was on the verge of collapse. The accidental discovery in 1878 of the fungicide, Bordeaux mixture, by a French, Prof. Millardet of the University of Bordeaux, saved the situation. This was an important event in the history of plant pathology when chemical control of plant diseases was in sight. However, in 1943, undivided Bengal suffered from a great famine not recorded in the history of mankind and two million people died of starvation The principal cause for the low rice production in that period was due to a disease called Brown leaf spot caused by a fungus *Helminthosporium oryzae* In the plant pathological literature, the Bengal epiphytotic of 1942 was equated to the Irish potato famine of 1845.

In India, serious studies in fungi (mycology), including plant diseases caused by some of them (pathology), started with the establishment of Imperial (Now Indian) Agricultural Research Institute at Pusa (Bihar) in the first decade of this century. E J. Butler, the first Imperial mycologist of the Institute, is regarded as the father of Indian Mycology and Plant Pathology. He studied and suggested control measures for a large number of crop diseases, viz., wilt of pigeon-pea, cotton and sesamum, disease of palm, betel, sugar cane, paddy, potato, maize, groundnut and rusts of wheat. He wrote a very useful book entitled *Fungi and Diseases in Plants*. Some of his contemporary Indian plant pathologists were J.F. Dastur noted for his work on late blight of potato, G.S. Kulkarni for his studies on downy-mildew of bajra and jowar; S.L. Ajrekar for his investigation in wilt of cotton and smut of sugar cane. By 1930, K.C. Mehta had made name for his studies on the wheat rust problem in India. Other noted Indian mycologists and plant pathologists are: B.B. Mundkur, R.N. Tandon, T.S. Sadasivan, S.N. Dasgupta, M.J. Thirumulachar, C. V. Subramanian and S.P. Raychaudhuri.

Later, the Institute was shifted to New Delhi, and is an active centre for plant pathological research. There are many research institutes under the Indian Council of Agricultural Research (ICAR) throughout the country which are engaged in researches into various aspects of plant diseases. The

main emphasis is laid on how to grow healthy crops for more food production for the increasing population of our country. Plant pathology deals with not only the disease symptoms but also the life cycle or etiology of the causal organism, its perpetuation in nature and the methods of control.

The word pathology is derived from the Greek *pathos*, meaning suffering; and *logos* meaning to speak.

Classification

Plant diseases are classified in various ways: (1) on the nature of causal organisms or pathogens; (2) on the symptoms caused by pathogens; (3) on the degree of the prevalence of a disease; and (4) in relation to the occurrance, perpetuation and mode of transmission of causal organisms in nature.

(1) *Classification Based on Pathogens*

What is a pathogen ? It is an agent that generates suffering and is always associated with a disease. The word is derived from the Greek words: *pathos*, meaning suffer; and *genesis*, meaning origin.

Pathogens are numerous and diverse. They are generally classified as *animate*, *viral*, and *inanimate*.

Animate pathogens: These are usually microbial in nature. There are others of animal origin, like nematodes and insects which also cause diseases. Among the microbial pathogens, fungi play a leading role followed by bacteria. The fungus *Helminthosporium oryzae* causes brown leaf spot of rice, while black arm of cotton is caused by a bacterium *Xanthomonas malvacearum*. Mango malformation is due to mites.

Viral pathogens: It is still problematical whether viruses are to be considered as animate or inanimate. But these cause diseases and, hence, are considered pathogens. And these are dealt with separately here. Some viral plant diseases are mosaic, veinclearing, chlorosis, etc.

Inanimate pathogens: There are many diseases whose cause cannot be attributed to any pathogen. Whiptail of cauliflower and apple scab are common examples. The former is due to the molybdenum deficiency in the soil and the latter is due to the respiratory gaseous product of apples in cold storage. Pathogens in these cases are inanimate and include chemical, gas, smoke, mineral nutrient, moisture, temperature, etc. Excess or deficient supply of these in the environment may cause a disease. The important 'Khaira' disease of rice is due to the zinc deficiency in the soil.

(2) *Classification Based on Symptoms*

A symptom is the result of the host-parasite interaction. Often the growth of a pathogen is visible on the host surface (localized) like a powdery or cottony mass. In others, the host is deformed, whereas in some the entire plant droops down due to the host-parasite internal interaction (systemic). Following are the symptoms produced by various pathogens.

(*a*) *Mildew:* Pathogen is seen as a superficial growth on the host surface. Pathogens of downy mildews exhibit cottony downy growth while in powdery mildews, the fungus appears powdery superficially. Examples: Green ear or downy mildew of *Pennisetum typhoides* (*Bajra*) caused by *Sclerospora graminicola* and powdery mildew of grapevine (*Vitis vinifera*) caused by *Uncinula necator*.

(*b*) *Rust:* The symptom is rusty or reddish-brown in appearance. Pustules appear beneath the epidermis which ultimately ruptures exposing a mass of spores. The pustules may be yellow, red, brown or black in colour. Example: Wheat stem rust caused by *Puccinia graminis tritici*.

(*c*) *Smut:* The word smut means sooty or charcoal-like powder. The symptom of this disease is mostly seen in inflorescences. The affected parts of the plant are transformed

into black spore mass. In sugar cane smut disease, caused by *Ustilago scitaminae*, the whole floral axis is transformed into a black, dusty whip. Loose smut of wheat is caused by *Ustilago tritici*.

(*d*) *White blister:* Pustules develop on the stem and leaves. The pustules appear elevated and shiny white in the infected inflorescence. The floral parts show various forms of deformity. Example: White rust of crucifers caused by *Albugo candida*.

(*e*) *Scab:* The term refers to a crust seen on the host surface The surface of the host becomes rough due to the formation of lesion. Example: Apple scab caused by *Podosphaera leucotricha*.

(*f*) *Sclerotia:* Sclerotia are hard compact mass of hyphae formed by different pathogens. It may be purple, brown or black in colour. Example: Ergot of rye caused by *Claviceps purpurea*.

(*g*) *Exudation:* This is a symptom associated with bacterial diseases. Bacteria ooze out of the host and are seen as a thin coating or glistening drops on the host surface. Example: Bacterial blight of rice caused by *Xanthomonas oryzae*.

(*h*) *Colour changes:* This is commonly the expression in viral diseases. Different terminologies are adopted for the differing colour patterns in plants. Chlorosis is the whitening or yellowing of the entire leaf. Colour-changes sometimes result in a mosaic pattern. Vein-clearing is a symptom where the tissues close to the veins turn yellow while the remaining areas remain green. When the tissues close to the veins remain green and the other undergo chlorosis, it is known as vein banding.

(*i*) *Hypertrophy or overgrowth:* The pathogen causes an abnormal increase in the size of plant parts or organs. This is known as hyperplasia and hypertrophy. Hyperplasia is an increase in the number of cells and hypertrophy is individual enlargement of the size of cells. The resulting growths are known by different names like gall, club-root, root-knot, etc. Example: Stem gall of *Coriandrum sativum* (coriander) caused by *Protomyces macrosporus*.

(*j*) *Atrophy or undergrowth:* Sometimes, plant parts may be arrested in their growth either partially or even entirely. Example: In a mustard plant attacked by *Perenospora brassica*, there is suppression of floral buds.

(*k*) *Witche's broom:* Numerous slender branches develop from a limited region and look like a broom Witches broom of mango inflorescence is a common example

(*l*) *Necrosis:* It means the death of the cells, tissues and organs The death of the cells is sometimes restricted to a small area resulting in spots. Leaf spots are familiar symptoms produced by fungi. In some leaf spots, the dead tissue of the spot is shed, leaving a circular perforation called a shot-hole. Spots may also appear in stripes.

(*m*) *Blight:* Blight indicates the burnt appearance of leaf or plant parts. This is a result of the instant death of foliage due to the pathogen. Example: Late blight of potato caused by *Phytopthora infestans*.

(*n*) *Damping off:* Various saprophytic fungi usually cause damping off of seedlings under certain conditions. They attack the base of the stem (hypocotyl) or the roots, thus making the tissue weak in that region; as a result, the seedling collapses. Example: Species of Pythium causes damping off of tobacco seedlings.

(*o*) *Wilt:* In some cases, the entire plant wilts. This is either due to an accumulation of the pathogen in the vascular tissues causing obstruction to the movement of water and food or due to the toxic substances secreted by them. Example: Banana wilt caused by *Fusarium oxysporum & F. cubense*.

(*p*) *Canker:* Canker is a dead area in the bark or cortex of a stem. Example: Citus canker caused by *Xanthomonas citri*.

(3) Classification Based on the Degree of the Prevalence of a Disease

In nature, diseases may be *endemic*, *epidemic* or *sporadic*, depending on their prevalence. When a disease recurs in an area, year to year, either in a mild or severe form, it is called *endemic*. Epidemic is a term applied to those diseases which occur widely but not periodically. It is systemic when an entire plant is affected. Sporadic diseases are those which occur infrequently.

(4) Classification Based on the Occurrence, Perpetuation and Transmission of Causal Organisms

Diseases can also be classified on the basis of their perpetuation in nature, viz, (*i*) seed-borne, (*ii*) soil-borne, (*iii*) water-borne and (*iv*) air-borne. Pathogens that are perpetuated and transmitted in soil are soil-borne pathogens. Accordingly, pathogens that are transmitted and perpetuated in seed, water and air are seed-borne, water-borne, and air-borne, respectively. Many diseases may be soil-borne at one stage of their cycle and seed-borne at the other stage.

The above classification is followed in detailing the diseases in this text.

Control of Plant Diseases

There are various methods to control plant diseases. But before undertaking any attempt to control a disease, one should possess a good knowledge of the following: the nature of the causal agent involved, the life cycle of the pathogen; whether the pathogen is living or not; the mode of survival of the pathogen in nature; predisposing factors, i.e., environmental conditions which influence the establishment of the disease and the factors that are responsible for its spread. Therefore, every control measure varies with each type and nature of a disease. One has to judiciously select the proper method. Generally, measures to control plant diseases are classified into the following three major categories:

1. *Prophylactic* measures to prevent the healthy plants from contact with the pathogens
2. *Therapeutic* measures to cure the plants which are already diseased.
3. Immunization measures to improve resistance in plants to fight against a disease.

1. *Prophylactic Measures*

Exclusion: Certain diseases can be avoided or excluded by observing the following precautions :

(*a*) *Quarantine:* In 1914, the Government of India passed "Destructive Insects and Pests Act" (DIP Act) which forbids the entry of diseased plant materials into the country. Only certified seeds or plant materials are allowed to enter the country or offered to growers. The plant quarantine stations work at every major sea and air port and prevent the entry of diseased materials. In early days, there was no regulation to control such entries and thus late blight of potato was introduced into Ireland from South America.

(*b*) *Eradication*· This is another useful measure to avoid diseases. The avoidance of disease by eradication can be achieved in several ways:

(*i*) CROP ROTATION: Continuous cultivation of one particular crop intensifies the inoculum of a pathogen. Crop rotation, by planting non-susceptible hosts, may eliminate the pathogen owing to the non-availability of suitable host plants or plant remains. Crop rotation is practised for wilt of *arhar* (*Cajanus cajan*) caused by *Fusarium audum* and foot rot of betel (*Piper betle*) caused by *Phytopthora nicotianae* var. *parasitica* and *Sclerotium rolfsii*.

(*ii*) ELIMINATION OF ALTERNATE AND COLLATERAL HOSTS : The removal of alternate hosts

prevents the perpetuation and spread of a disease. The control of black stem rust of wheat by the eradication of barberry bushes which was an alternate host was achieved in the USA. In India, such a method is suggested for controlling blast of rice where some perennial grass hosts (collateral) are the source of primary inoculum.

(*iii*) ROGUEING OF DISEASED PLANTS : Rogueing of the affected plants constitutes one of the routine control methods in plant virus diseases.

(*iv*) FIELD SANITATION : This method is applicable when pathogens perennate either in the soil or in the diseased plant debris. The various measures are: removal of the diseased plant debris and its burning; deep ploughing to bury the diseased plant and plant parts; hot weather deep ploughing; and use of chemicals to disinfect the fallen plant debris.

(*v*) ERADICATION OF THE SEED-BORNE INOCULUM : Many diseases are internally or externally seed-borne. Methods like sieving, steeping in water or brine solution are used to separate the diseased from the healthy seeds. Chemical seed treatment with formaldehyde, or compound of mercury, copper or sulphur eradicates the inoculum present externally on the seed surface. Internally seed-borne pathogens that may be deep-seated in the embryo are destroyed with hot water or solar treatment.

(*vi*) BIOLOGICAL CONTROL : This signifies the control of one disease causing organism with the help of another living organism. This results in a reduction in the incidence of a disease caused by a pathogen. For example, a pathogen, a nematode or fungus may be parasitized by another fungus or bacterium. Usually, antagonism exists commonly in soil between microorganisms living side by side, some inhibiting the growth of others. Organisms compete with one another on the host surface, and by changing the environment the antagonistic microbes can be stimulated to grow and inhibit the pathogen. The roots of certain higher plants secrete toxic substances that check the pathogen.

(*vii*) PROTECTIVE APPLICATION OF CHEMICALS : When the disease is expected with wind-borne inoculum, control measures involve the application of specific toxic substances to the host surface These substances which are toxic to the pathogen and not the host include compounds of sulphur, copper, zinc, nickel, manganese, etc. They are used as spray or dusts

2. *Therapeutic Measures*

Therapy is a measure to cure a plant which is already diseased. It tries to relieve the plant of symptoms and repair the damages caused by the pathogen. During therapy, the cause of the disease is removed so that the normal living function of the plant is restored. Therapeutic measures are of two types : (a) Physical therapy and (b) Chemotherapy.

(*a*) *Physical Therapy:* This method involves physical means such as surgical moisture and temperature treatments to fight the disease. The infected tissues of a plant are removed to prevent progressive and additional damage. Intracellular humidity is a factor concerned with disease development in a large number of plants. In such cases, the diseased plants may be cured by controlling intracellular humidity. It retards the development of bacterial soft rot and other diseases. Immersion in hot water with or without antiseptics has often been found effective in controlling disease development.

(*b*) *Chemotherapy:* A pathogen may infect or injure only surface cells in a localized area or a tissue. Also, an entire part of a

plant may be systemically invaded. The treatment of the former is topical chemotherapy, whereas the treatment of the latter is systemic chemotherapy. In chemotherapy, the disease is fought with chemicals which may either act topically or systemically, depending upon the situation. A chemotherapeutant is a compound that directly or indirectly initiates a curative or mitigative effect.

In many diseases, commercial success has been achieved through topical chemotherapy. Seeds internally infected with bacteria and fungi are treated with suitable concentrations of diathiocarbamate, phenol, formaldehyde, vapour which penetrate the seed and kill the pathogen *in situ*; infected potato tubers are dipped in formalin or mercuric chloride solution before planting. In systemic chemotherapy the pathogen is chased up to the farthest leaflet of the host plant. Chemicals are distributed systemically within the plant to kill the pathogen by direct toxic action. Also, chemicals are absorbed by the roots and translocated to the leaves. Phenylmercury-acetate, sulfanilamide and related sulfa compounds, antibiotics and auxins are examples of systemic chemotherapeutants.

COMMON FUNGICIDES AND ANTIBIOTICS USED IN CONTROLLING PLANT DISESASES

(*i*) *Bordeaux mixture:* It is a mixture of copper sulphate and lime in a 4 : 4 ratio dissolved in 50 gallons of water. This is one of the best known fungicides discovered since 1878. This is widely used in controlling many types of crop diseases of economic importance, viz., downy mildew of grape, tikka disease of groundnut, coffee rust, etc

(*ii*) *Sulphur dust:* Inorganic sulphur is one of the oldest and most widely used fungicides. Early Greeks knew its use. It can be used in powder form or in wettable form which can be dusted or sprayed. Sulphur dust is used against powdery mildews.

(*iii*) *Organic compounds with heavy metals:* Agrosan GN, Gersan and Tillex are organomercury compounds used in seed treatment. They effectively control a number of seed-borne diseases, e.g., brown leaf spot of rice. Diathiocarbamate fungicides like Diathane M-45, Diathane Z-78 control Tikka disease of groundnut. *Alternaria* blights of cereals, vegetables and fruit crops, etc., are controlled by Diathane M-22, Diathane S-31.

(*vi*) *Antibiotics used as fungicides*· Several antibiotics are used to control disease-causing fungi and bacteria. Penicillin, streptomycin, cycloheximide, Griseofulvin and viridin are used to control plant disease. Streptomycin is very effective against bacterial diseases, many of which were uncontrollable for a long time. Cycloheximide and Griseofulvin are antifungal antibiotics which have been found to be very effective. Agrimicin controls bacterial blight of rice and Blasticidin is used to fight blast of rice.

3. *Immunization Measures*

Immunization measures are the best means for effectively controlling plant diseases. The host plants are made immune or resistant to infection by parasitic causal agencies. Resistant varieties can be obtained by the following ways:

(*a*) *Selection of disease-resistant varieties:* It is often found during epiphytotics that within a good variety under cultivation some plants show a better degree of disease resistance than others. Careful selection of such plants and their large-scale cultivation produce varieties of high disease-resistant quality.

(*b*) *Plant introduction:* Plant introduction has been one of the oldest methods of crop improvement. It is a common practice to introduce new varieties of plants from a distant area where they have shown good results of disease resistance, to a new area that has been infested with various diseases. This practice of plant introduction is

generally between distant localities or countries with variable climatic conditions.

(c) *Breeding disease-resistant varieties.* Breeding of permanent disease-resistant varieties is the best way for controlling plant diseases. It is known that resistance is caused by certain genetic factors Therefore, first, the physiological and anatomical characters of the host that are useful in building resistance against the attack of the pathogen are studied in detail. Then detailed knowledge of the pathogen and the disease process is acquired. Then a cross is made between the disease-resistant and disease-susceptible varieties of parents, resulting in a new variety which is generally cultivated. Improved strain K.I. of *Bajra* has high field resistance to green ear disease.

EXERCISES

1. What are the general symptoms of plant diseases ?
2. Give brief historical accounts of the following :
   (a) Bengal famine
   (b) Irish potato famine
   (c) Mycology and plant pathology
   (d) Bordeaux mixture
3. Cite an example each of viral, bacterial and fungal diseases studied by you. Describe the symptoms and give control measures for any one of them.
4. Comment on any two of the following :
   (a) Predisposing factors play an important role in disease development.
   (b) Prophylactic measures are the best ways to control disease.
   (c) The chemotherapeutant chases the pathogen up to the leaf tip of the host plant.
5. How are plant diseases classified ?
6. Distinguish and differentiate a healthy plant from a diseased one.

CHAPTER 28

Some Important Plant Diseases of India

IMPORTANT plant diseases can easily be studied under the following heads: (1) Seed-borne, (2) Soil-borne, (3) Air-borne, and (4) Those propagated through plant parts.

1. Seed-borne Diseases

Important *seed-borne* crop diseases in India are : (i) Brown leaf spot of rice, (ii) Ergot disease of Bajra, (iii) Red rot of sugar cane, (iv) Bacterial blight of rice, and (v) Black arm of cotton. In nature, the seed-borne pathogens follow a general pattern of disease cycle. One such disease cycle is illustrated in Fig. 28.1. The pattern may vary from one disease to the other. The diseases are described below with their symptoms, disease cycles and methods of control.

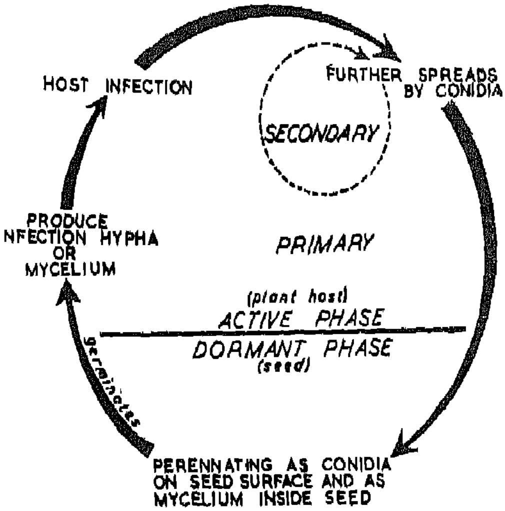

Fig 28.1 Brown leaf spot disease cycle of rice (Seed-borne).

(i) *Sesame Leaf Spot or Brown Leaf Spot of Rice*

PATHOGEN: *Helminthosporium oryzae* (Fungus)

Helminthosporiose or brown leaf spot disease caused a severe loss in yield in the Krishna Godavari area in 1918-19 and in undivided Bengal in the year 1942. Loss in grain yield varying from 50 to 90 per cent was recorded. This disease is mostly found in the southern and western regions of the country.

A clear understanding of the factors and conditions responsible for the onset and development of the disease will help the rice-growers to plan and practice healthy and proper cultivation.

SYMPTOMS

Minute circular brown spots having a

dark central zone with a brown marginal ring appearing on the leaves, (Fig. 28.2) leaf sheaths and glumes. The seed becomes shrivelled and discoloured.

Fig. 28.2 Brown leaf spot or sesame leaf spot of rice: *A*. Infected leaf; *B*. Affected grains (black).

DISEASE CYCLE

The primary infection is likely to be severe when the soil temperature at the sowing season falls below 26°C. Experiments have shown that the pathogen remains viable in the seed for a year only till its next growing season. The air-borne conidia play an important role in spreading the secondary infection. The secondary infection can cause a severe incidence of the disease at the adult stage of the crop. High humidity with periodic showers, rather than prolonged rainy season, favours conidia output and its dissemination. Conidia cause infection between 20° to 35°C in the presence of water. The infection is rapid in darkness than in light The plants are highly susceptible when they are in "boot" or at the flowering stage. A sudden rise in relative humidity and fall in the range of daily temperature and cloudiness are the factors which generally favour the outbreak of the disease.

CONTROL

The seeds are treated with organo-mercurials at 1 : 300 parts by weight before sowing. Hot water treatment of the seeds at 55°C for 10 minutes is also quite effective in reducing the seed-borne infection. The secondary infection which is air-borne can be checked by spraying 5:5:50 Bordeaux mixture or Diathane Z-78 twice or thrice during the season. Resistant varieties like *T-141* (Orissa), *C-0.20* (Madras) and *T-498-2A* (Bihar) are reported to be quite promising in India.

(ii) *Ergot of Bajra*

PATHOGEN: *Claviceps microcephala* (Fungus)

SYMPTOMS

The disease becomes evident when small droplets of pinkish or light honey-coloured fluid (honeydew) exude from the spikelets of the spike. Later, these exudates become dark and finally several agglomerated dark, sticky patches are seen on the ear. Eventually, small dark-brown sclerotia are seen projecting in between the glumes. Seed setting may be inhibited.

DISEASE CYCLE

The infection takes place through the flower. The disease spreads by conidia which retain viability for a period of 13 months and invade the ovary.

CONTROL

This disease is seed-borne. Therefore, the ergot-free seeds should be used. Dip the seeds in 20 per cent sodium chloride or 30 per cent potassium chloride. The diseased seeds float and the healthy ones sink. The latter are washed in water and sown in the field.

(iii) *Red Rot of Sugar Cane*

PATHOGEN: *Colletotrichum falcatum* (Fungus)

This disease causes severe damage in India, especially in Eastern Uttar Pradesh and Bihar.

SYMPTOMS

The infected cane splits, gives an alcoholic smell and shows red tissues with white cross bands. The leaves wither and the cane shrinks, showing black specks on the shrivelled rind (Fig. 28.3).

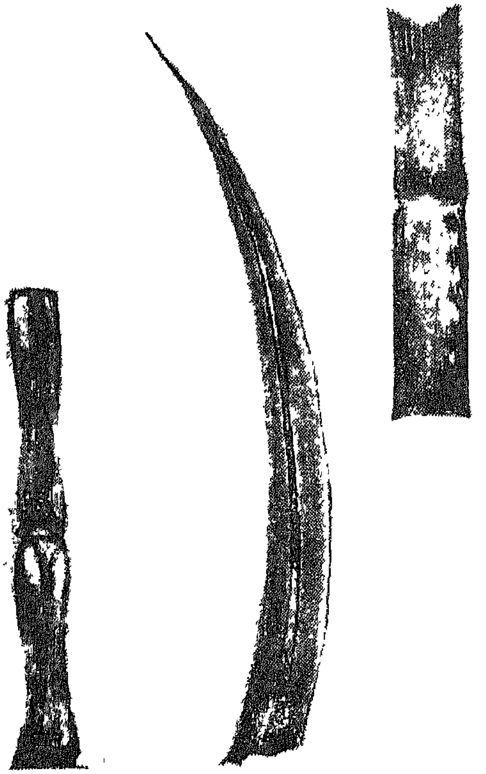

Fig. 28.3 Red rot of sugar cane: *A*. Infected stem; *B*. Infected leaf.

DISEASE CYCLE

The disease spreads through setts (seed cuttings). The secondary infection takes place by conidia which are abundantly produced in the leaf midrib lesions.

CONTROL

Healthy setts should be used. Resistant varieties of plants may be grown.

(iv) *Bacterial Blight of Rice*

PATHOGEN: *Xanthomonas oryzae* (Bacterium)

Bacterial blight of rice came into India with the introduction of high-yielding Japanese varieties like Taichung. This disease was well known in Japan since the beginning of the century. It has caused extensive damage in India during the last decade.

SYMPTOMS

The disease occurs from July to October and appears as pale-green or greenish-yellow lesions either on one or both the leaf surfaces. The lesions spread and coalesce with each other producing long wavy stripes. The yellowish stripes later become straw-yellow with light-brown wavy margins. In most cases the diseased leaf starts drying up from its tip downwards. In severe cases of infection, the whole field gives a burnt up appearance.

DISEASE CYCLE

The pathogen survives both internally and externally in the seed, stubble and straw

and is the source of primary inoculum which progresses intravascularly. The bacterial exudate produced on the diseased leaves constitutes a rich source of secondary inoculum and its dispersal is facilitated by rain splashes, insects, irrigation water, etc.

CONTROL

The seeds are soaked in a mixture of 0.025 per cent solution of Agrimycin and 0 05 per cent wettable Ceresan for 12 hours. Then these are transferred to hot water at 52°–54° C for 30 minutes and then sown. Better water management in fields should be practiced

(v) *Black Arm or Angular Leaf Spot of Cotton*
PATHOGEN: *Xanthomonas malvacearum* (Bacterium)

This is a serious bacterial disease of cotton. It occurs in all major cotton-growing regions of the world and was first reported from Madras in 1918.

SYMPTOMS

The bacterium attacks all aerial parts of the young and old plants. The earliest symptom of the disease is seen in the cotyledons of the germinating seeds. Minute, water-soaked spots appear on the leaves which turn dark-brown having a reddish or purplish margin when old. Long and dark-coloured lesions are also seen on the stem (Fig. 28.4).

DISEASE CYCLE

The disease is seed-borne. The primary infection is mainly from a seed which harbours the bacterium as a slimy mass on the fuzz or inside the seed. The infected cotton bolls, leaves and twigs present on the soil surface also form an important source of carry-over for the disease. The leaves are infected mainly through the stomata. The secondary dissemination of the disease is caused by rain splashes and dew.

Fig. 28.4 Angular leaf spot or black arm of cotton.

CONTROL

The seeds are treated with conc. H_2SO_4 for 10 to 15 minutes. Then, they are washed in water to remove the acid thoroughly. Finally, the seeds are treated with agrosan GN, ceresan at the rate 2 to 2.5 gm per kg of seeds. The bacterium lives in the seed for about a year only and, therefore, storing the seed for two years before sowing is recommended.

2. Soil-borne Diseases

Some soil-borne diseases are: (i) Green ear of bajra, (ii) Smut of bajra, (iii) Tikka of groundnut, and (iv) Root knot of tomato. The primary inoculum being in the soil source, control measures lie in the

management and treatment of the soil. A typical Tikka disease cycle of groundnut is shown in Fig. 28.5.

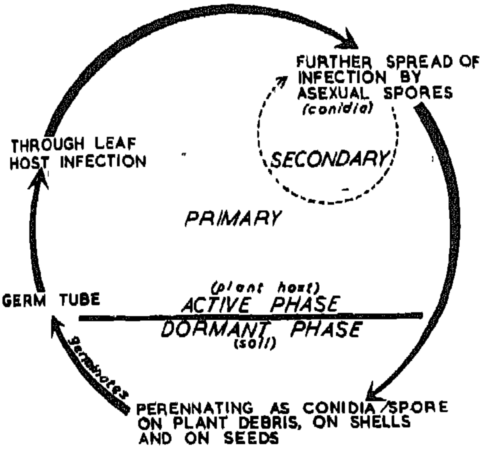

Fig. 28.5 Tikka disease cycle of groundnut (Soil-borne).

(i) *Green Ear Disease of Bajra*

PATHOGEN: *Sclerospora graminicola* (Fungus)

Bajra, the pearl millet, grows in a relatively poor soil and forms the crop of the arid and semi-arid areas in Rajasthan, Gujarat, Maharashtra, Punjab and Uttar Pradesh. Grown with simple cultural practices, it forms the basis of Indian food economy. The important disease occuring in all bajra-growing areas of India is the green ear disease. An annual of 40 to 50 per cent of the crop is estimated in Rajasthan, Punjab and Delhi alone. It was Butler who first investigated the disease in India.

SYMPTOMS

The affected leaves become white and, later, the brown whitish downy growth of sporangia appear on the lower surface of the leaves. The ear or the inflorescence transforms, wholly or in part, into the loose head of small, twisted, green leaflike structures (Fig. 28.6).

Fig. 28.6 Green ear disease of bajra.

DISEASE CYCLE

It is a soil-borne disease. The oospores that have fallen to the ground with the debris of the plant germinate when favourable conditions appear. Sporangia, which cause the secondary infection, are carried in wind, water and by insects.

CONTROL

Not much work has been done on the

control aspects of the disease Treatment of the infected seeds with agrosan GN as been suggested to reduce the infection. Hot water treatment is also helpful. A disease-resistant variety of bajra like *HBI* is recommended for cultivation

(ii) *Smut Disease of Bajra*

PATHOGEN: *Tolyposporium penicillariae* (Fungus)

SYMPTOMS

The affected grains are scattered in the ear and project prominently beyond glumes like pear-shaped bodies. The column is bright-green or chocolate-brown, and, when old, becomes dirty black with the enclosed spores mass deep-brown or black in colour.

DISEASE CYCLE

The plants become infected at the flowering stage by the soil-borne spores. The secondary infection by teleutospores spreads the disease in the crop.

CONTROL

Burn the infected plants and grow resistant varieties.

(iii) *Tikka Disease of Groundnut*

PATHOGEN . *Cerospora personata, C arachidicola* (Fungus)

Leaf spot of groundnut, often assuming serious proportions, is reported from all over India. This is popularly known as the Tikka disease.

SYMPTOMS

Numerous necrotic circular spots, each varying from 4 to 10 mm in diameter, appear on both the surfaces of the leaf. Sometimes these spots are surrounded by a yellow halo at maturity (Fig. 28.7).

DISEASE CYCLE

The disease perpetuates yearly from the conidia that lie in the soil within the fruit

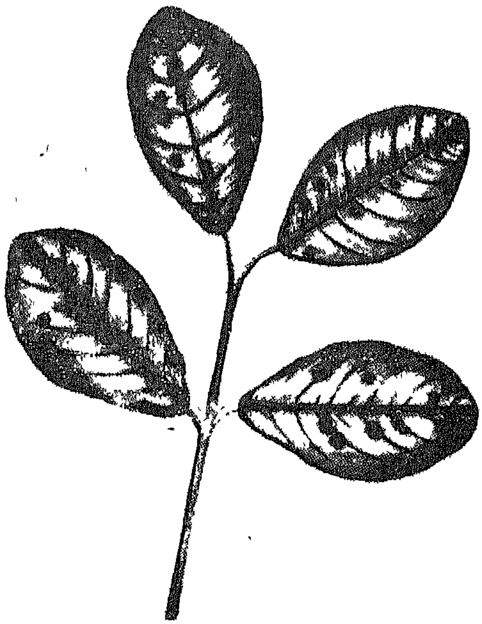

Fig. 28.7 Tikka disease of groundnut.

shells or in the plant debris.

CONTROL

Bavistin, diathane Z-78 (0.2 per cent) and diathane M-45 are some of the fungicides used to control the disease. The disease spreads due to the magnesium deficiency. Therefore, fertilisers containing magnesium should be applied to the soil.

(iv) *Root Knot of Tomato*

PATHOGEN: *Meloidogyne hapla* (Nematode)

It is a nematode, parasitic in the root of tomato plants.

SYMPTOMS

This nematode infection reduces the growth of the plant, induces sudden wilting, and causes gall formation on the roots resulting in their clubbing. The larvae penetrate into the pith of the root where the growth of the latter is arrested and the cortical cells enlarge considerably (Fig. 28.8).

DISEASE CYCLE

The female nematodes and larvae survive in the soil and the plant debris. These infect the roots. The female reproduces parthenogenetically.

Fig. 28.8 Root knot of tomato.

CONTROL

Biological control of the nematodes is achieved by planting *Tagetes* in the field. The roots of *Tagetes* have toxic effect on the nematodes. The tomato root residues are destroyed and the soil fumigants used. Ploughing the field twice or thrice in summer kills the larvae of the nematodes.

3. Air-borne Diseases

The diseases perpetuated annually through the primary inoculum present in air are: (i) Blast of rice, (ii) Rust of wheat and (iii) Coffee rust. The general method of control lies in using resistant varieties and fungicides. Fig. 28.9 shows the typical life cycle pattern.

(i) *Blast of Rice*

PATHOGEN: *Piricularia ozyzae* (Fungus)

This is the most important disease of the rice plant and occurs all over the world. It is common throughout India.

SYMPTOMS

The spindle-shaped lesions appear on the

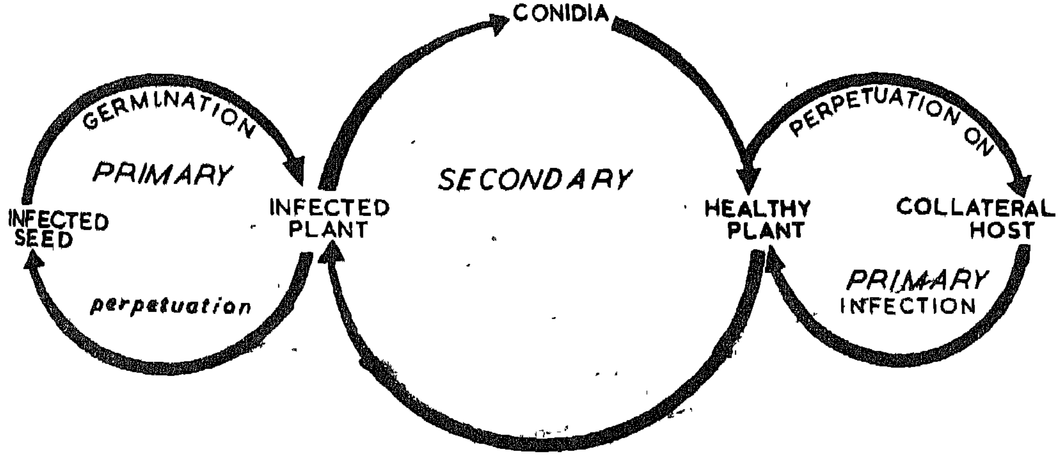

Fig. 28.9 Blast disease cycle of rice (Air-borne).

leaves. The spots are ash-coloured in the middle with a brown margin. In severe cases, the plants wither at the seedling stage. In others, the nodes are blackened and break at the joints. If the neck is attacked, the earhead may fall in the field. The grains may remain unfilled and become chaffy (Fig. 28.10).

Fig. 28.10 **Blast disease of rice. The symptoms are shown at the different regions of the plant body.**

DISEASE CYCLE

The origin of the infection in nature is still not understood clearly. In the hills, the fungus remains viable throughout winter in the infected straw and other plant debris and thus causes the disease cycle. But in the plains the chance of its survival in the plant parts or in the soil through the hot summer is remote. It is still not precisely understood how the disease cycle operates in the plain from season to season. Air-borne conidia are the most important means for dissemination of the pathogen. Dissemination may also take place through the seed, straw, or from the conidia that fall in irrigation water. The researches carried out at the Central Rice Research Institute, Cuttack (CRRI) have shown that a night temperature ranging from 20° to 25° C, with a relative humidity of 90 per cent and above, and lasting a week or more, are ideal for the blast outbreak. The susceptible growth phases are either the seedling stage or the tillering stage or at the flower emergence.

CONTROL

An antibiotic known as blasticidin is sprayed on the crop. The resistant varieties of crops recommended are *Co4*, *Co25*, and *T 141*.

(ii) *Rust of Wheat*

PATHOGEN: *Puccinnia, graminis tritici*(Fungus) for black stem rust.

Of all the plant diseases occurring in India, wheat rust has been the subject of detailed study as is evidenced from the work of K. C. Mehta in the field. The different types of wheat rust are:

(a) Black stem rust
(b) Brown leaf rust
(c) Yellow stripe rust

Here, we deal with only the black stem rust disease.

SYMPTOMS

Brown pustules of uredosori appear on the leaves, the leaf-sheaths and the stem. These pustules grow and fuse to form bigger dark-brown lesions. The height of the plant is retarded and there is poor tillering with poor shrivelled grains (Fig. 28.11).

DISEASE CYCLE

The source of the primary infection is the

Fig. 28.11 **Black stem rust of wheat, showing the symptoms on the leaf surface and leaf health.**

uredospores (asexual) formed on the wheat crop grown in the hills throughout a year. These uredospores, blown by wind, reach the plains and infect the wheat crop. Another alternate plant host, *Berberis vulgaris*, is needed to complete the sexual life cycle of the fungus. However, this plant species is not found in India and hence the life cycle of the fungus is not complete. The infection is, therefore, mainly by uredospores.

CONTROL

Rust-resistant varieties are grown in India.

(iii) *Coffee Rust*

PATHOGEN: *Hemileia vastrafix* (Fungus)

The rust caused by *Hemileia vastrafix* is the most serious disease of arabica coffee in south India.

SYMPTOMS

Orange-yellow spots with spores appear on the leaf surfaces with dry brown patches on the upper surface. In acute cases of infection, defoliation occurs (Fig. 28.12).

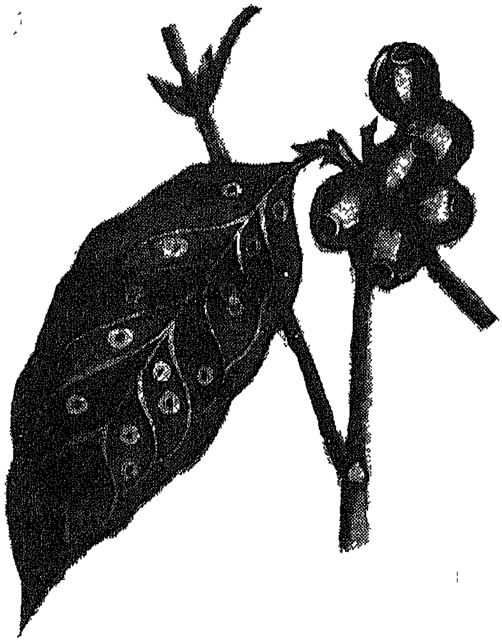

Fig. 28.12 **Coffee rust, showing the symptoms on the leaf surface.**

CONTROL

Our country has made considerable progress in combating this disease by evolving resistant coffee strains for different types of rust. Copper fungicides are also being used extensively. Bordeaux mixture (2.2.50)

may be sprayed on the lower surface of the leaves a month after the occurrence of blossom showers.

4. Diseases Propagated through Plant Parts

Some diseases repeat yearly through plant parts or are transmitted by insects. The best examples are: (i) Blister blight of tea, (ii) Banana bunchy top, (iii) Potato mosaic, and (iv) Mango malformation. In plants, viral disease transmission occurs through insects. Banana bunchy top disease cycle (viral) is shown in Fig. 28.13.

(i) *Blister Blight of Tea*

PATHOGEN: *Exobasidium vexans*

SYMPTOMS

Small yellow spots are formed on the leaves. The upper surface of the leaf develops a shallow depression whereas the lower surface becomes greenish-white bearing spores (Fig. 28.14).

DISEASE CYCLE

The pathogen is an obligate parasite and since the tea crop is perennial and grows throughout the year, the inoculum exists endemically in the plantation.

CONTROL

Spray with perenox (6 oz. in 15 gallons of water per acre) or dust with 4 per cent cuprosan (10 lb per acre) once in every week or ten days.

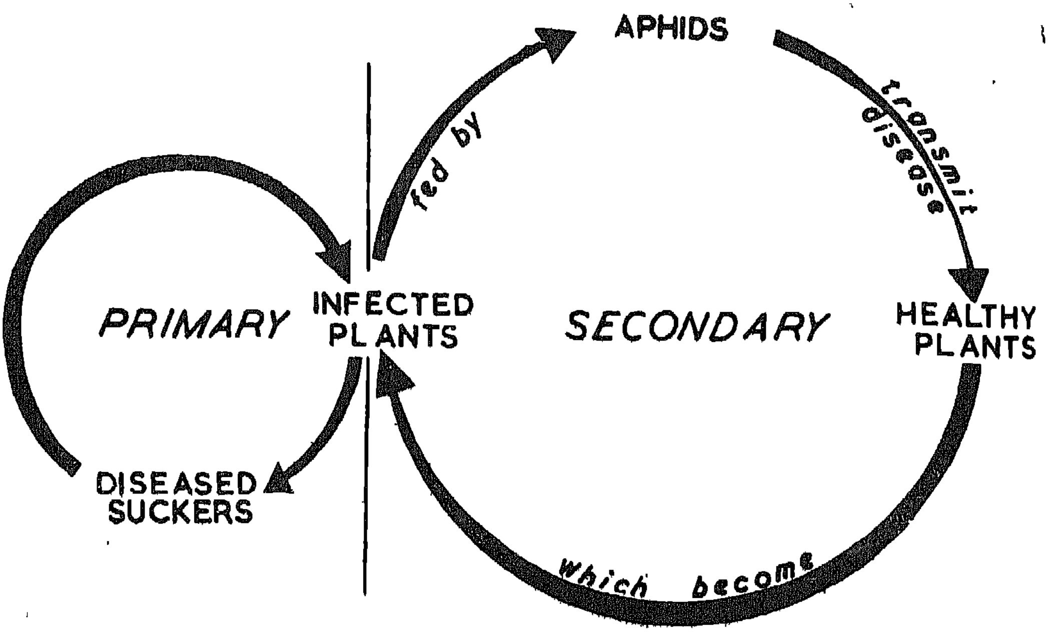

Fig. 28.13 Banana bunchy top disease cycle (Insects and plant parts).

(ii) *Banana Bunchy Top*

PATHOGEN: *Banana virus I*

The bunchy top disease of Banana occurs in eastern and southern India.

SYMPTOMS

The affected plants usually remain stunted and all the leaves develop in a dense rosette-like fashion at the apex. During the initial

phase, green streaks appear on the midrib, petiole and lower surface of lamina. Marginal chlorosis and curling of the leaves take place.

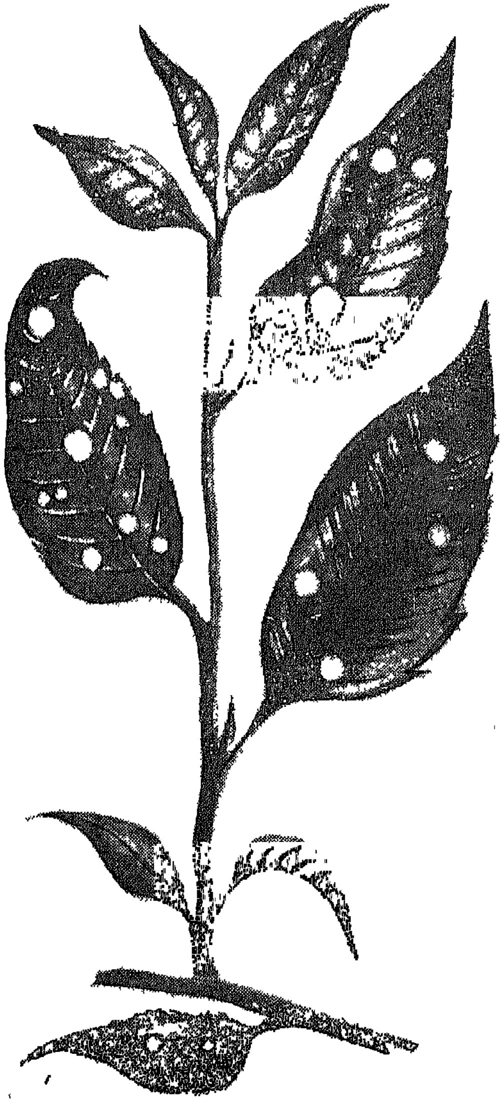

Fig. 28.14 **Blister blight of tea.**

DISEASE CYCLE

The infection is caused by planting diseased suckers. The secondary infection is through an aphid (*Pentalonia nigronervosa*) during the growth of the plant.

CONTROL

Diseased plants should be uprooted and burnt. Planting material should be properly checked before propagation.

(iii) *Potato Mosaic*

PATHOGEN: Potato virus X, or *Solanum virus I*

There are several viral mosaic diseases of potato. We will deal with one here: potato virus x causing latent mosaic.

SYMPTOMS

Mottling of the leaves is a characteristic symptom of this disease. The plants may become stunted. The leaves and tubers may show necrotic spots (Fig. 28.15)

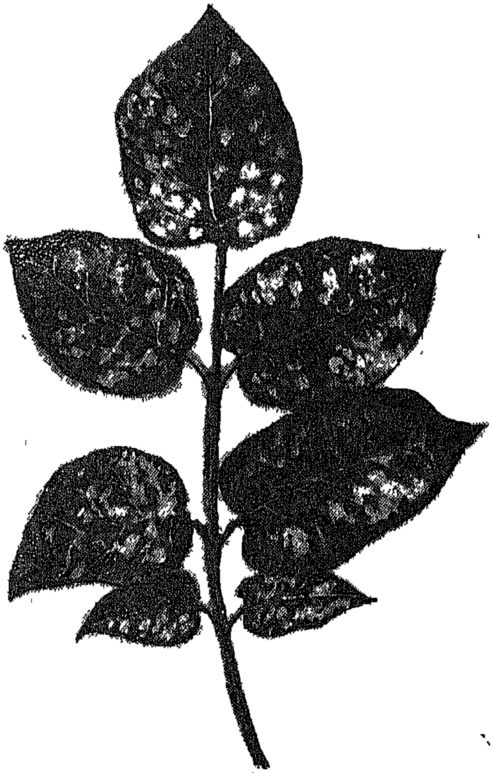

Fig. 28.15 **Mosaic disease of potato.**

DISEASE CYCLE

Under field conditions, the disease spreads by contact and the virus is sap-transmissible.

CONTROL

Resistant varieties should be grown which will combat the infection to a large extent.

(iv) *Mango Malformation*

PATHOGEN: *Eriophyses* spp. and *Tyrophagus castellani* (Mite)

Malformation of the mango plant is a disorder prevalent in north India. Malformation is due to the infestation by mites (*Eriophyses* sp., *Tyrophagus castellani*) which results in an abnormal growth.

SYMPTOMS

Floral branches of the infected plants are crowded in the form of a cone. The peduncle becomes thickened and fleshy with profuse branching. Fertile flowers are rare. The entire inflorescence turns black. Fruits are seldom formed and profuse development of numerous small leafy structures occurs in the place of flowers, resulting in a witches' broom appearance. Each group of leafy structures represents a malformed floret.

CONTROL

Systematic removal of the affected shoots controls the spread of the disease. Spraying of insecticides (basudin, ekatin, systou, etc.) kills the mites.

EXERCISES

1. Draw a diagram showing the root knot disease of tomato and mention its pathogen. How is this disease controlled?
2. What is rust? Describe the symptoms of the black stem rust of wheat and give its control measures.
3. Through labelled diagrams only show the symptoms of the blast disease of rice, bacterial blight of rice, coffee rust and smut disease of bajra.

CHAPTER 29

Plant Pests

PESTS ARE animal or plant organisms which damage cultivated plants or plant products. Roughly calculated, one-third of the potential crop yield of cultivated plants is lost through pest action between sowing, harvest, storage and consumption. The average annual world potato harvest is estimated at 200 million tons. Even if there would be a four per cent loss, this would amount to eight million tons. Apart from the loss in economy, it is a greater loss that the valuable food goes waste. Particularly in our country, valuable staple food crops like rice and wheat are not only lost in the fields due to infection but are also consumed and destroyed by rodents and infection in granaries. Every kilo of grain lost or damaged would have certainly fed a needy family. Therefore, it is not only important to improve our crop plants but also much more important is to be vigilant and to protect the crops from any pests both in the fields as well in the storehouses. This can be successfully achieved only if we have thorough knowledge of the various pests of the various crops. In other words, it is not only important to know the crop but is also equally important to know its pests and their control-measures as well.

Classification of Pests

Pests are generally classified as follows:

(i) Arthropods (Jointfooted invertebrates)
   (a) Insects like grasshopper, caterpillar, gundhy bug, fly, beetle, cotton bollworm, mites, khapra beetle, rice weevil, red grain beetle, lesser grain borer pulse beetle, angoumois grain moth, etc.
   (b) Non-insect arthroped like crab.

(ii) Molluscs—snail, slug

(iii) Mammals—rodent, monkey, wild elephant, etc.

(iv) Birds—pigeon, parrot, sparrow, crow.

(i) *Arthropods*

Arthropods are jointfooted animals. These include insects like grasshopper, caterpillar, bug, fly, beetle, etc. They cause enormous damage in agriculture, forestry and to livestock. Insects bore into the stem, feed on flowers and fruits, provide entry points for other pathogenic organisms, excrete toxic substances and transmit viral diseases.

The control of insects is done by spraying insecticides. The pests imbibe the insecticide when feeding, or are affected and killed by mere contact with the poison.

Mites attack mostly herbaceous plants. They suck juice from the leaves. The

infected leaves initially exhibit white spots which become yellow to brown before death. On the lower surface of leaf, webs are woven within which eggs are laid and larvae emerge.

Mites are controlled by organophosphorus compounds, acaricides and sprays containing DNOC preparations. These insects use plant parts as food, penetrate the interior and secrete toxic substances. The larvae feed on the leaves.

Crabs cause serious damage to the paddy crop by cutting young plants at the ground level These are controlled by hand-picking, trapping in pots, using baits and placing cooked rice mixed with 50 per cent DDT in burrows.

(ii) *Molluscs (Snails and Slugs)*

Slime tracks on the plant surfaces characterize snails. These animals cause damage by rasping feeding. They feed on tender leaves, seedlings, soft bark and fallen fruits. They are best controlled by hand-picking and are killed by molluscicides like mataldehyde which can also be used as a bait with wheat bran. The application of caustic fertilizers controls the snails.

(iii) *Mammals (Rat, Rabbit, Wild Elephant, etc.)*

Rats and mice cause considerable damage to our crops both in the field and in storage. They consume foodgrains as well as pollute the stored products. They are carriers of many diseases. Due to the agile movements of these animals and their hidden way of life, it is difficult to control them. Zinc Phosphide is mixed with food and offered as a bait to kill the rats. Monkeys and the langur, in particular, attack, in troops, vegetable gardens and fruit orchards. Rabbits, deer and wild elephants feed enmasse on crops and cause serious damage.

(iv) *Birds*

Many birds, e.g., the house sparrow, parrot, pigeon and crow feed on grains or seeds, fruits, etc. They are controlled by capturing them with traps, sealing their hideouts with mud, removing the eggs from the nests, using scares and exhibition of dead birds. It should be noted that some of these birds also keep the insect population down by feeding on them. Therefore, any method to control these birds should be pursued judiciously. Further, sparrows and crows can also be combated with meat or chicken-egg baits poisoned with strychnine, arsenic and phosphorous. These poisons affect other animals also. Therefore, great caution should be exercised when using these baits.

Some Important Plant Pests

Stem Borer of Rice (Tryporyza incertulas)

It is an important pest of paddy (Fig. 29.1). The moth is yellowish with black spots on the forewings. The insect bores into the stem of rice plants. The central shoot withers and produces dead heart.

CONTROL

The stubbles should be destroyed after harvest to kill the hibernating larvae. The seedlings are treated in 0.1 per cent DDT suspension before transplantation. The mature crop is sprayed with a 0.025 per cent parathion or 0 08 per cent endrin in the field at the rate of 270 to 360 litres per acre.

Rice Grasshopper and Brown Plant Hopper of Rice (Hieroglyphus banian)

This insect devours leaves and tender grains of the paddy crop. The nymphs as well as adults feed on the plants.

CONTROL

The pest can be controlled by deep ploughing after every harvest. The plants should also be dusted with 5 to 10 per cent BHC at the rate of 90 litres per acre. The spraying

Fig. 29.1 Rice stem borer: A. Male moth; B. Female moth; C. Egg mass on rice leaf; D. Caterpillar in stem; E. Pupa in stem; F. Empty panicle

of 0.02 per cent aldrin at the rate of 270 to 360 litres per acre checks this pest.

Gundhy Bug or Paddy Bug (*Leptocorisa varicornis*)

The adult bug is elongated, brownish, 14 mm long with long slender legs. The bug sucks the milky sap in the tender grains. Sometimes the crop is destroyed completely.

CONTROL

The plants are shaken so that the young nymphs drop in water. Five per cent of BHC at the rate of 5.5 to 6.8 kg per acre kills the nymphs.

Spotted Bollworm of Cotton (*Earias fabia*)

This is a small stout brown caterpillar which bores into the top shoots of the cotton plant in the early stage and into the bolls later on (Fig. 29.2). The top shoots droop down and the attacked bolls are shed. The adult is a pale-white moth with a wing expanse of 25 mm.

CONTROL

The infected shoot and bolls should be destroyed. Remove all stumps after harvest. Spray 360 to 450 litres of 0.03 per cent endrin per acre at fortnightly intervals.

Pink Bollworm of Cotton (*Pectinophora gossypiella*)

This is a small dark-brown moth with several black spots of different sizes on its wings; it has a wing expanse of 12.5 mm. The pale or deep pink caterpillar bores into bolls and seeds and also pupates within the bolls (Fig. 29.3)

CONTROL

The fallen buds and bolls should be removed. The pest can be controlled by spraying endrin (20 per cent) or folithion (0.2 per cent).

Coconut Caterpillar (*Nephantis serenopa*)

It is a serious pest of coconut found along the coastal areas from Cape Comorin to Bombay in the west and south of Madras to Bengal in the east. The adult is a medium-sized moth with a wing expanse of 20-25 mm. The caterpillar is green in colour with a sparse covering of hair. It feeds on the leaves. The attacked plants can be recognised at a distance by the scorched appearance of its fronds.

CONTROL

The infected fronds should be destroyed. 0.2 per cent DDT at the rate of 4.5—9. litres per tree should be sprayed.

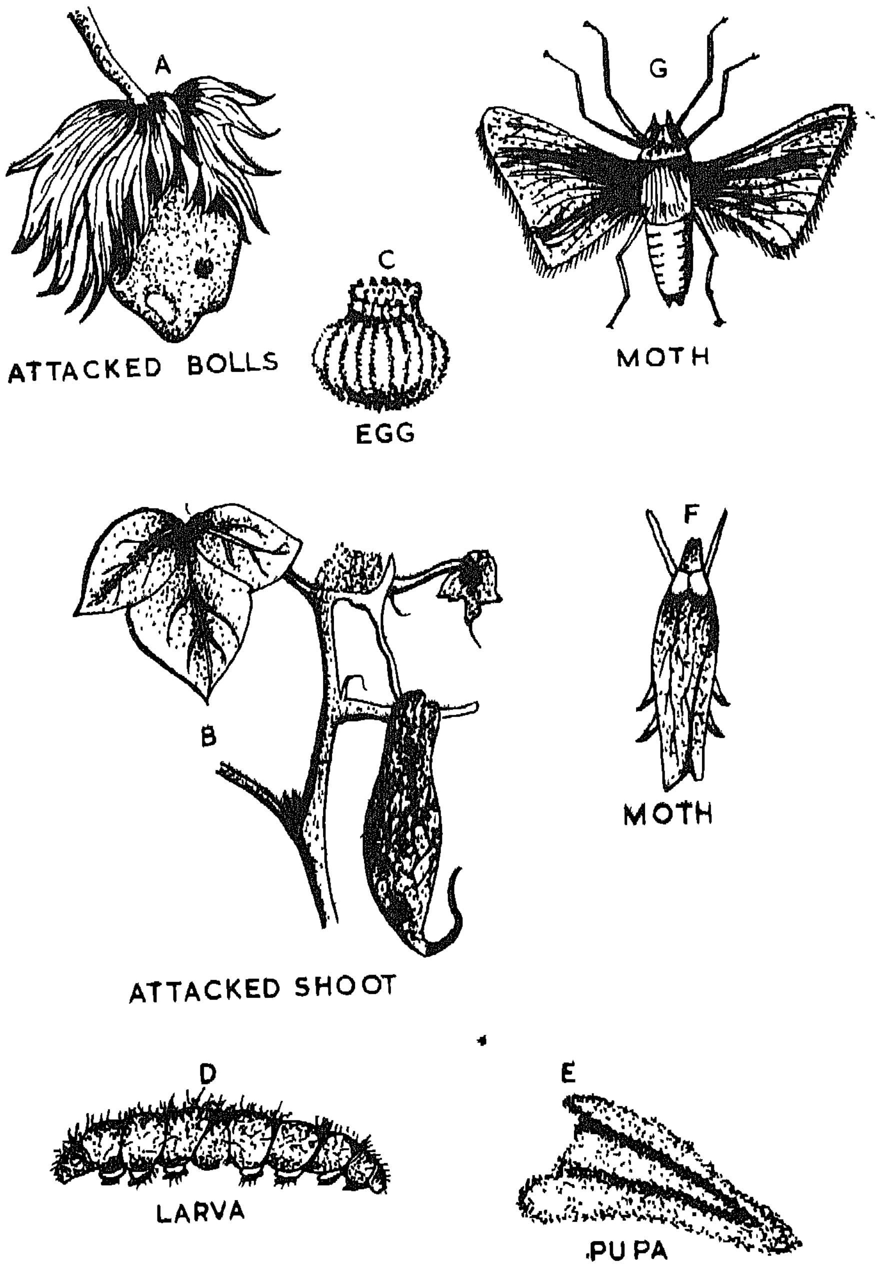

Fig. 29.2 Spotted bollworm of cotton: *A*. Attacked **bolls**; *B*. Attacked shoot; *C*. Eggs; *D*. Larva; *E*. Pupa; *F&G* Adult.

***Tobacco Caterpillar* (*Prodenia litura*)**

This is a stout, dark moth with white wavy markings on its forewings (Fig. 29.4). This caterpillar feeds on the leaves.

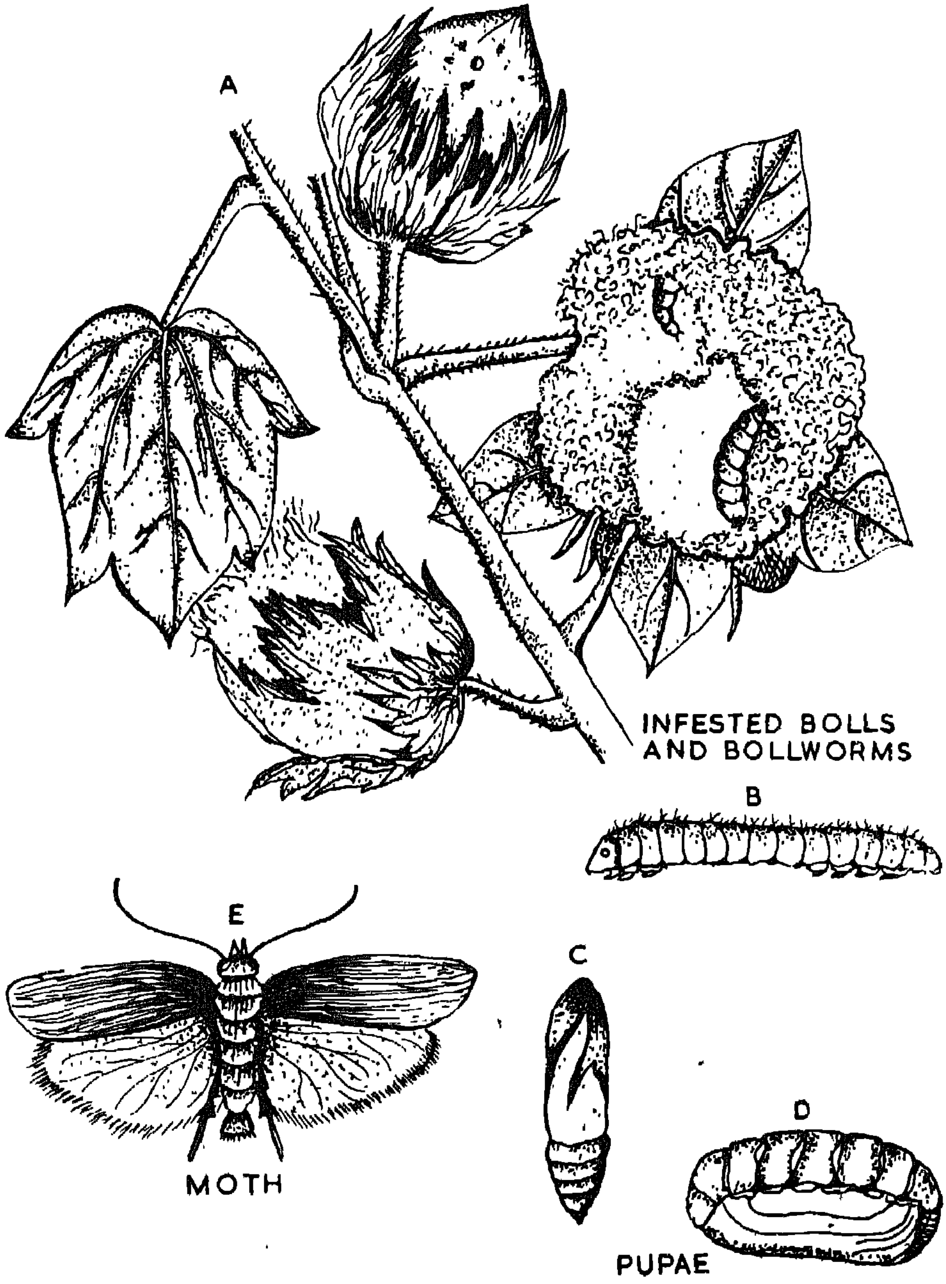

Fig. 29.3 Pink bollworm of cotton: *A*. Infested bolls and bollworms; *B*. Larva; *C&D*.Pupae; *E*. Moth.

CONTROL

Ten per cent BHC powder, 5 per cent DDT or 2 per cent parathion at the rate of 7 to 10 kg per acre.

Storage Pests of Rice and Pulses

Khapra Beetle (*Trogoderma granarium*)

It is a brown oval beetle, about 2.5 mm long (Fig. 29 5). The grubs (Larvae) are

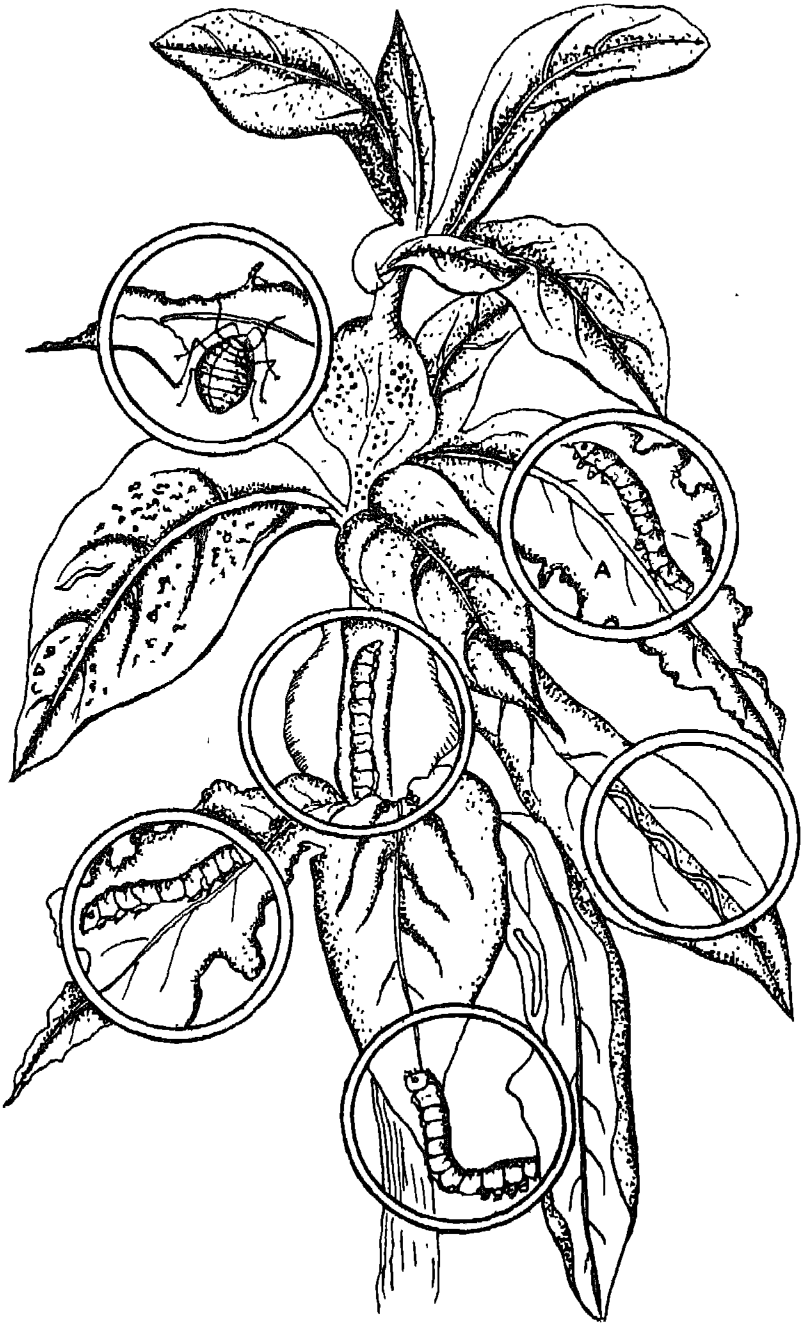

Fig. 29.4 Pests and diseases of tobacco: *A*, *Prodenia* caterpillar.

Fig. 29.5 Larvae of khapra beetle.

brownish-white with bundles of reddish-brown hair all around their body. They feed on cereals and pulses. However, infestation is restricted to the top layer of storage.

Rice Weevil (Calandra oryzae)

This small animal (Fig. 29.6), measuring about 2.5 cm in length and reddish-brown in colour, is world wide in distribution. Apart from rice, the adults and grubs feed on all cereals and millets.

Red Grain Beetle (Triboleum castaneum)

The reddish-brown, 1.5 mm long beetle or its pale-yellow grubs feed on the broken grains and flour of cereals, millets, pulses, groundnut, dry fruits, etc. This insect is also known as rust red flour beetle.

Lesser Grain Borer (Rhizopertha domnica)

This beetle, about 1.5 mm long, black to brownish-black in colour with a globular head, bores into the grains of cereals, pulses and millets and destroy them. Their grubs are white in colour.

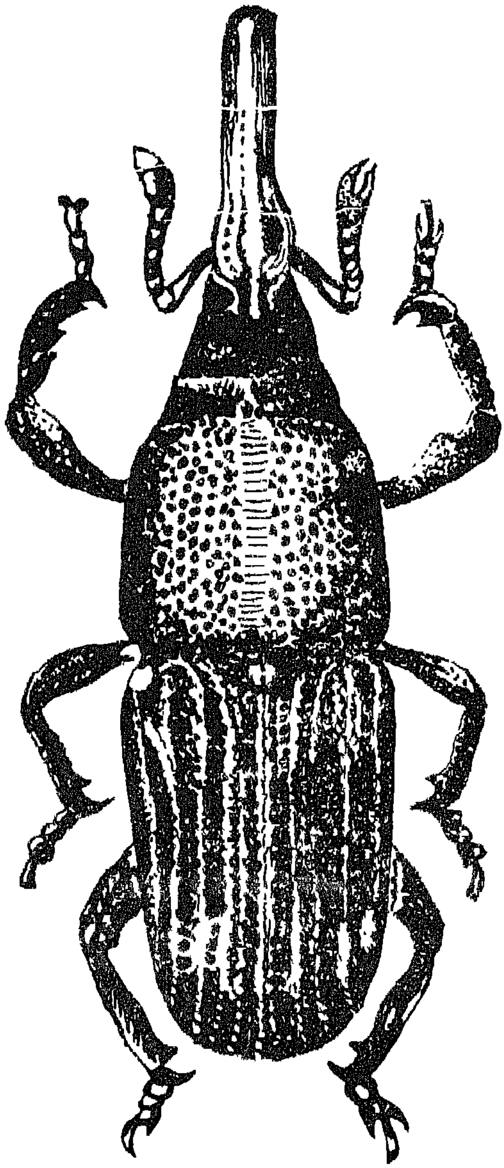

Fig. 29.6 Adult rice weevil.

Rice Moth (Corcyra cephalonica)

This is a dark-grey moth that lays eggs anywhere in stores and godowns. The

eggs hatch into creamy-white caterpillars within five days and feed on the grains by boring holes. The caterpillar spins a silkweb entangled with bits of grains, etc. The moth also attacks oil seeds and dry fruits.

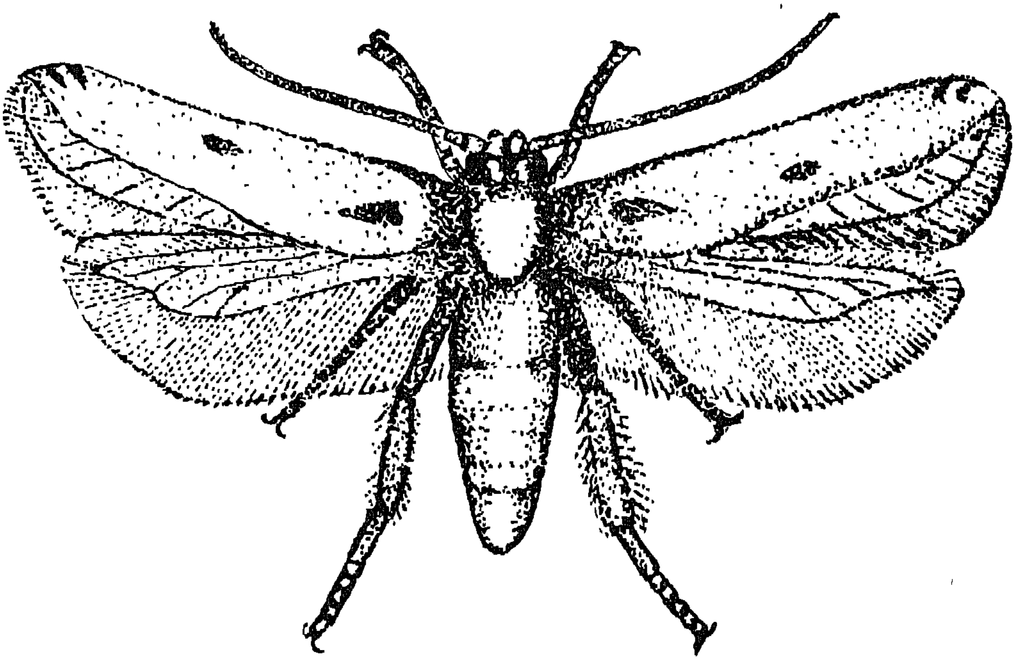

Fig 29.7 Angoumois grain moth.

Angoumois Grain Moth (*Sitotroga cerealella*)

This is a 12 mm long, shiny buff-coloured moth with pointed, narrow wings having wide fringes (Fig. 29.7). The caterpillar bores into the grains of cereals and millets and makes them hollow. The female lays several hundred eggs within the grain cracks. This is an important moth pest of unmilled grains.

Pulse Beetle (*Bruchus* spp.)

There are many beetles of the genus *Bruchus* which are chocolate-coloured (Fig 29.8). The adult and the grub bore into the grains or pods of pulses Some of these beetles breed only in the stores, whereas others breed in the fields causing considerable damage to the standing crops.

Apart from the above pests, there are many others like the ant, cockroach, rat, etc., which feed directly on the stored grains.

CONTROL

The storage pests are generally controlled in well-ventilated godowns. The ceiling and the floor should be smooth, without cracks and crevices. There should not be more than ten per cent of moisture in the grain. Only one kind of grain should be stored in a godown. The bags should not touch the walls. The wall and ceiling surfaces may be sprayed with 0.5 per cent lindane or malathion at 0.5 litre per 100 square metres.

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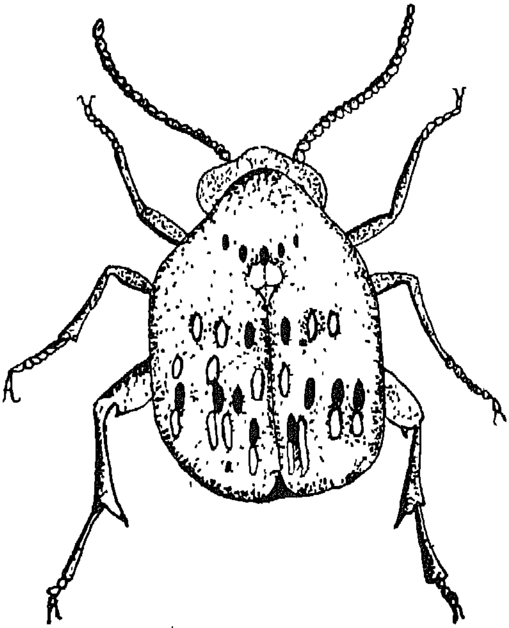

Fig. 29.8 Pulse beetle (*Bruchus* spp).

EXERCISES

1. What is a pest ? Give a general description of the pests that you have studied.
2. Name the important rice pests. Describe the nature of the damage they cause and their control measures.
3. Fill up the blanks :
   (i) The Bengal famine was due to .... disease of rice.
   (ii) Banana bunchy top is caused by ....
   (iii) Khapra beetle is a .. . . pest.
4. What are the general methods of control of the storage pests ? How do we control the rodents which also feed on the storage grains ?
5. Describe the identifying features of the following storage pests :
   (i) Rice weevil
   (ii) Angoumois grain moth
   (iii) Pulse beetle
6. Write short notes on the following :
   (i) Stem borer of rice
   (ii) Gundhy bug of rice
   (iii) Cotton spotted bollworm
   (iv) Coconut caterpiller.

CHAPTER 30

Forests in the Service of Man

PLANTS, especially trees, are companions of man since his appearance on this planet. He had been living in thick jungles, hunting animals for his food. The word 'forest' (Latin *Foris*—outside) means a land outside the fences and boundaries of villages covered with a closed canopy of trees and shrubs. It differs from the Indian word 'Jungle' in having regularly grown and managed trees. In other words, the forest is an ecosystem comprised of both living and non-living components. Any area of land continuously stocked with different species of trees of different ages and regularly managed to get an optimal yield of products in the existing environmental conditions can be categorised as forest. The branch of knowledge concerned with scientific rearing and tending of forest trees in order to derive the maximum benefit is known as forestry. It is a science involving the study of nature, working with nature and not competition with nature.

Glancing through the history of civilization one finds that forests were closely related to the life of man. The collection and protection of woodlands was in practice during the fourth century B C. About 10,000 years ago, while roaming in forests, man discovered that certain seeds could be grown as food. He started growing and cultivating these seeds and developed more and more land for agriculture by cutting and burning trees. After some years when the land became less productive, he moved to other forested areas and repeated the attack. This process of cutting trees to increase land area for agriculture is technically known as shifting cultivation and it preceded agriculture. The Aryans, being pastoral people, used to practice such methods but at the same time they had a taste for inspiring landscape and surroundings. The human population was small and forests were in plenty during that period. As the human population increased rapidly, the needs of man also multiplied and this resulted in his increased onslaught on forests. In Mahabharata, also, forests were destroyed on a large scale. This led our ancestors to declare the cutting of trees a sin. Some wise men by adopting measures such as above could save the trees like Pipal, Banyan and Bal, etc., from extinction. Emperor Ashoka also realized the importance of forests and ordered the planting of useful trees along the highways.

In recent times, particularly during the two World Wars, the destruction of forests was accelerated especially in our country

during the British regime as they realized the importance of timber for manufacturing navy ships and railway sleepers to feed the war machine In India, after the 1955 Forest Policy Act, the Government made serious efforts to improve forests, but the resulting development could not match the pace of destruction and depletion of the forest capital.

After independence, in 1950, our Government launched a tree saving and plantation movement named *Van Mahotsava*. In order to make forests play their role in the nation's welfare, National Forest Policy was implemented in 1952. This policy highlighted the protective, productive and bio-aesthetic role of forests. On the basis of functions, the national policy envisaged the classification of forests into protection forests, national forests and village forests. The focus of the policy was on the establishment of treelands, ensuring increasing supplies of grazing land, timber and firewood. It also warned against the indiscriminate extension of agriculture at the cost of forests, thus depriving the land of its natural defences against dust-storm, hot winds and water erosion.

Our Forest Wealth

Forest is considered as an industry which plays a significant role in strengthening the economy of a nation. Forests supply raw materials for manifold uses in everyday life and directly or indirectly feed our industries. Forests anywhere play a major role in conserving the fertility of the soil, checking erosion and controlling the climate of the area Though they are perpetually renewable natural resources, they are not inexhaustible.

Indian forests comprise of a large variety of trees due to the variation of factors like climate, physiography, soil, water conditions and biotic communities. In the classification of world forests, the major parts of Indian vegetation are classified as monsoon and dry forests, thorn bush and savanna. There are about 2500 species of trees. Our forests are spread over 17.2 per cent of the total geographical area of the country. The useful species grow mixed with other tree species, except for sal and chirpine. Table 30.1 shows that the total annual increment of forests in use is very less as compared to other countries. The area under forests in India is also less than in other countries.

TABLE 30.1

Basic statistics of forests in various countries

	India	*Asia*	*UK*	*USSR*	*USA*
a) Total forests (Million hectare)	56	520	1.5	1 131	316
b) Forests in use (Million hectare)	45 6	200.7	135.2	453.5	213 7
c) Annual increment of forests in use (per hectare)	0.5	2 6	3.5	1 9	3.0

Indian forests can be broadly classified as broad-leaved, evergreen (deodar forests) and needle-leaved deciduous (oak forests) where trees become leafless during certain seasons.

The forest wealth can be described as the direct yield of a number of products from forests for meeting the domestic demands of people or for providing raw materials for industries. The important commercial products from forests are timber, paper, plywood, resin, gum, lac, etc.

Forest products can be classified as :

(i) Major —Wood

(ii) Minor —Animal, vegetables and mineral products

We will study in brief each one of these products, their nature and use.

(1) ***Wood or Timber***

The fundamental process of photosynthesis in plants uses air, water and, with the help

of sunlight and chlorophyll, manufactures starches and sugar. These get converted into various components of wood like lignin and cellulose. Wood is made up of a special type of cells called fibre cells. These cells contain a white substance—cellulose—which appears brown after lignin coating. The fibre cells only make a timber heavier and stronger. The forest trees which yield wood are broadly categorised as hardwoods and softwoods. The majority of Indian forest trees like sal, teak, shisham, eucalyptus, etc., are among the hardwoods whereas the needle-leaves trees like conifers, deodar, pine constitute the softwood group.

Wood generally meets various needs of man. The knowledge of the structure and properties of wood is essential for its most profitable use. Based on its use, wood can be classified as industrial wood and fuel wood. More than 2000 species of Indian forest trees yield timber having multiple uses. The suitability of wood for a particular purpose can be determined after testing only. For example, *Acacia chundra* was found to be hard self-lubricating wood for aircraft propellers in place of *Lignum vitae*. Wood is also used for making bridges, railway sleepers, fence posts, transmission poles, plywood, tool handles, toys, sports materials, furniture etc. The best for a specific purpose and its suitability is generally described in books on forest utilization.

More than 85 per cent of the total wood is used as fuel. The measurement of calorific value and heating value helps in labelling the wood either good fuel or bad fuel.

Paper

The fibrous nature of wood helps in using it for making pulp, paper and rayon. About 4000 years ago Egyptians prepared writing paper from reed and named it reed papyrus from which the word paper has been derived. Conifer-fir, spruce, etc., having needlelike leaves are most suitable raw materials because of lengthy wood fibres. Bamboo is also extensively used as raw material. Till the last century wood was the raw material for paper-making. The chips of wood or bamboo when cooked in chemicals give wet fibre mass (pulp) which after beating in a beater is filtered and dried for use.

The progress of a nation perhaps can be estimated from the per capita index of use of all kinds of paper. As shown in table 30.2, India has the lowest per capita paper consumption.

TABLE 30.2

Consumption of paper in different countries

Country	*Per Capita (Paper consumption in kg)*
India	1.4
USA	205
UK	106
USSR	16
Japan	57
World	26.7

The estimated requirement of paper in 1980 will be 6 kg per capita. The shortage of long-fibred species like conifers and bamboos has necessitated the means to develop and increase plantations of short fibre woods like eucalyptus. The latter has much more yield (10 tonnes per hectare per year) as compared to the former (2.5 tonnes per hectare per year).

Plywood

It is a thin sheet of wood obtained by peeling and slicing the log of wood. The plywood consumption per 1000 individuals is very low (0.2 cubic metre) in our country as against 1.5 for Asia, 5.9 for the USSR, 48.0 for the USA and 6.7 for the world. Teakwood, rosewood and walnut are good

and suitable raw materials for obtaining plywood. Though our country imports plywood but is also increasing her own resources for its production. The cost of plywood can be reduced through the exploitation of other cheaper woods and the minimisation of wastage.

Resin

This is the exudation of some tree species Unlike gum, resin is soluble in alcohol. The Chir tree is an important source of resin in our country. A notch is made on the tree trunk a few centimetres above the ground and resin flows down along the notch into a cup This, on distillation, yields 25 per cent turpentine and 75 per cent resin. The latter is used in the making of soap and paints.

Gum

The cell walls of the gum producing trees after degradation give out a substance called gum. It exudes out when a tree gets wounded. Gum is used in confectionary and medicines The common gum-yielding trees are Babul, Salai and Dhaora. The Kulu tree's gum is used for thickening ice-cream. Trees should not be killed but tapped for a maximum yield of gum.

Medicinal Plants

A large number of herbs and trees yield raw materials which are used in the manufacture of drugs. Some of the most common trees yielding medicinal substances are mentioned below.

1. *Emblica officinalis (Amla)*: It is a deciduous tree found in forests and is also cultivated. Triphala, a laxative made from its fruits, is used for the enlarged liver and pain in the eyes. The fermented juice from the Emblica fruits is also used for indigestion, anaemia and jaundice. The fruits are a rich source of vitamin C.

2 *Madhuca indica (Mahuva):* It is a tall deciduous tree which grows in the Himalayas. At some places it is one of the chief constituents of forest vegetation. The decoction of the tree bark is employed in itching and bleeding gums. The leaves, after mixing with ghee, are applied on burns. The flowers are used against respiratory troubles.

3. *Butea monosperma (Pala, Flame of the forest)*: It is a medium-sized tree and is the host plant of lac insect. It grows in the dry deciduous forests all over India. The gum from the tree contains tannin and is used against diarrhoea. The seeds help in checking roundworms and tapeworms.

4. *Cinchona officinalis* . The bark of the tree yields quinine which is employed against malaria and bacterial infection. It is also used in eye lotions. Higher doses cause deafness, blindness and nausea.

5. *Atropa belladonna (deadly night-shade)*: The roots and leaves are dried at low temperature and pulverized. Inhaling the burning leaves of belladonna is good for asthma. Atropine, an alkaloid, is used to dilate the eye, and check the secretion and local pain.

5. *Pinus roxburghii (Chir)*: It is a tall tree with needlelike leaves and is found on the hills. The oil obtained from the tree acts as a stimulant and expectorant, and is useful in chronic bronchitis. It also helps in checking constipation.

6. *Pterocarpus marsupium (Kino tree)*: It is a tall tree found in mixed deciduous forests. It yields gum, named as kino gum, which is astringent and is useful in diarrhoea. Sometimes diabetic patients are given the wood-soaked water.

The fast-exploding human population is widening the gap between the demand and the supply through its continual increase of demands on forests. The onslaught on forests through cutting, destruction and depletion of forest capital also leads to soil erosion by exposure to wind and water, poor soil fertility, and change in climate.

The forestry or the application of scientific studies can improve upon the situation only when the individual and also governments realize the economy-strengthening role of forests. The benefits we derive from forests speak for their protection and conservation The inadequate forest area, livestock, low-value species and slow-growing species necessitate the minimization of waste and the adoption of scientific techniques. The afforestation of land, plantation of fast-growing and valuable species, protection of trees against fire, controlled grazing and least disturbance to the vegetative cover are some of the methods suggested for forest conservation.

EXERCISES

1. Define the term forestry.
2. Forests play a major role in the economy of a nation. Justify the statement.
3. What measures government has adopted to improve forests ?
4. What are hardwood and softwood ? Give examples in each case
5. Describe the uses of wood.
6. The per capita index of the use of paper is the index of the progress of a nation. Comment on the statement.
7. Name any two trees yielding
   (a) gum
   (b) resin
   (c) medicines
8. How forests can be conserved ?

CHAPTER 31

Forest Insects in the Service of Man

THE ANIMAL component of the forest ecosystem also plays a significant role in the welfare of mankind. These organisms spend their lives on forest trees. A large variety of industrial and commercial products are obtained from the forest fauna. Some tiny insects add a lot to the economy of forest as well as of the nation by producing raw materials for various industries. Some of the important varieties of insects are bees, moths and lac insects. Since time immemorial these have been found in natural forests. Their economic importance was felt with the advancing scientific knowledge. With the available techniques and resources people started nurturing these insects. We will study how these tiny animals help man for better living.

Apiculture (*Apis-bees, Culture-cultivate*)

Apiculture is the care and management of bees. As bees produce honey and wax, they are named as honey-bees. Mention in the Vedas and the Ramayana indicates that bee-keeping was in practice even then. However, the methods employed by the bee-keepers were very crude and uneconomic and this resulted in the wastage of honey and sometimes the death of the insects. It was only in the ninteenth century that some progress was made through the use of improved techniques which involved the invention and introduction of movable frame hives and honey extraction, respectively.

Bees are one of the few insects beneficial to man. The most common species of honey-bees in our country are *Apis dorsata*, *A. florea* and *A. indica*. These insects help in pollination in the nectar-producing flowers. Bee-bites have sometimes helped to a great extent to treat the muscular, nervous and sciatic pain, and rheumatism.

The place where bees are cultured and bred to get commercial products is known as apiary. The bee-keepers can improve their profession and make it quite profitable if they have (1) a definite number of colonies, (2) strong colonies of desirable strains, and (3) means to get and sell pure honey. Further, they require to understand the behaviour of bees, improve their race, and to have the knowledge of honey-producing plants and honey-flow conditions of the locality. In our country, the climate, the season of

flowering and the nature of vegetation are the limiting factors for bee-culture.

Honey is defined as aromatic, viscid, sweet material derived from the nectar of plants. It has two main sugars, *dextrose* and *levulose*, and other substances like moisture, pigments, enzymes, pollen grains, etc. The sugar is easily assimilable and is a ready source of energy. Honey helps in the building up of the haemoglobin of blood. It is also used in the baking of bread, biscuits, etc. In the Ayurvedic and the Unani system of medicine honey is used as a carrier of the active substance. It has been considered to be a laxative, a blood purifier, a preventive against cough and cold. It has been used in the making of alcoholic drinks, skin and beauty lotions and for preserving fruits.

Honey-bees also make wax commonly known as mom, sinthi, lelin, etc. This substance is made by bees in the hotter months. The wax colour is affected by sunlight. The main source of bee-wax in our country is *Apis dorsata* because of its larger comb. Wax has multifold uses. It is used as offerings in temples and churches. The finishing touches to various gold, brass and silver moulds are given by wax. It is used in making ointments, plasters and in printing industry.

Sericulture

The breeding and management of insects for the production of silk is known as sericulture. The insect *Bombyx mori*, commonly known as silkworm, is able to do something which other insects cannot.

Silkworms were observed in China on the host tree called the Mulberry (*Morus alba*). Since silkworms were banned to be taken out of China, these insects were brought to India in the form of eggs by a princess from that land. From the very beginning silkworms have not changed their eating habits. The mulberry can live without silkworms but silkworms cannot produce good silk without the mulberry. They are called worms because of a prominent wormlike stage in the life cycle of the silk-moth. Based on the host food, they can be classified as mulberry-feeding silkworms (domesticated) and non-mulberry-feeding silkworms (wild). J. Orington in 1689 observed that Indian climate favours too many breeds a year (six times) whereas in England it can breed only once. The crop of silk produced by a generation is called band.

Lac Culture

Lac is a resinous substance exuded from an insect and it is the only one of animal origin. The word 'Lac' comes from a Sanskrit word *laksha* meaning hundred thousand probably because of an innumerable number of larvae coming out of a single lac encrustation. The lac insect *Tachardia lacca* is practically endemic to India. The host plants on which this insect thrives are palas (*Butea frondosa*), ber (*Zizyphus jujuba*) and kusum (*Schleihera oleosa*). The quality of lac depends on the plant on which the insect feeds.

Lac cultivation begins with broodlack, an encrustation containing insects on the twig of a host tree. The insects then spread over the host trees, breed and secrete a resinous coating which gives lac. Four crops a year can be raised. The raw product is scrapped from the branches and washed with water to clear it from soluble impurities and thus *seedlack* is obtained. Seedlack is processed through a hot melting process to produce *shellac*. It is used in varnishes, polish, and in the preparation of gramophone records and printing ink, etc. It can also be used as stiffener in making felt hats and leather finish.

Lac also yields a red dye and resin lac. The latter is mixed with common resin and wax and is available in adulterated form.

EXERCISES

1. Define the term sericulture.
2. Write briefly the various uses of honey and bees-wax.
3. How apiculture can help man in better living ?
4. What is lac ? Give the scientific names of the insect and the host plant.
5. List the three species of honey-bees.
6. How lac is useful to man ?

CHAPTER 32

Livestock

CATTLE provide milk and milk products which, in turn, provide animal protein in the diet of the Indian people. Cattle play an important role in the agricultural economy of India. Cattle are the precious possession of a peasant, next to land. In agricultural operations in our country bullocks are extensively utilized as the motive power. Droppings from cattle forming manure are well known for maintaining the fertility of the soil and which are often misused as fuel. The hides of cattle are utilized for making a variety of leather goods. India is the largest exporter of hides and skins. Cattle, buffaloes, sheep, pigs, and camel constitute the livestock wealth of our country.

Our Cattle Resources

Cattle and buffaloes constitute the important category of our livestock. During 1965-66, India had a livestock population of 343 million, consisting of 176 million sheep, 64 million goats and other livestock. The average annual milk yield of a cow in India is 173 litres, while a buffalo yields 491 litres. It has been estimated that about 70 out of 100 cows and she-buffaloes give no milk at all. A vast majority of dairy cattle yield less than one litre of milk per day, whereas 20 per cent of buffaloes give at least two litres of milk per day. Milk yield and fat content are quite high in buffaloes as compared to cows. Added to this, a buffalo has better adaptability, disease resistance, and longevity. A buffalo is regarded as a poor man's tractor. Table 32.1 indicates the average annual milk yield of a cow in India and some other countries.

TABLE 32.1

Average milk yield per cow per annum

Netherlands	4220 kg.
USA	4250 ,,
Denmark	3710 ,,
UK	2990 ,,
Pakistan	420 ,,
India	220 ,,

Breeds of Cattle

There are several important breeds of cattle and buffaloes in India (Tables 32.2,32.3) They are distinguished by their body build, colour, nature of the horns, forehead and geographical distribution Some of them produce good working bullocks while in some cases cows of the breed are good for milk production.

TABLE 32.2

Important breeds of cattle in India

Amrithmahal	Deoni
Gir	Haryana
Kangayam	Kankrej
Malawi	Nagori
Ongole	Red Sindhi
Sahiwal	Tharparkar

TABLE 32.3

Important breeds of buffaloes in India

Murrah	Nagpuri
Jaffarabadi	Mehsana
Nili-Ravi	Surti

Feeding of Cattle

The old adage says that the best milk comes from contented cows. Paucity of feed and fodder is responsible for low milk production in our country. A balanced feed consists of appropriate quantities of nutrients like carbohydrates, fats, proteins, minerals, vitamins and water. Feeds are divided into two general classes, roughages and concentrates. Roughages contain large amounts of fibre which include hay, fodder and silage. The concentrate mixture is made up of grains and seed by-products like cereal and gram bran, rice polish cotton seed cake. Mineral nutrients are also given as a supplement to the common feeds.

Grasses are the most common and nutritious feed of cattle. Sudan grass, Rhodes grass, Napier grass, Guinea grass and Elephant grass are some of the fodder grasses which are highly nutritious. Agathi, Berseem, Lucerne, Cowpea and other leguminous fodder are highly nutritious and relished by cattle. The fate of cattle is miserable in times of floods and famine. Some fodder banks have been set up for supply to scarcity areas Green forage is conserved for dry months as hay or silage (succulent form of green fodder).

Dairy Products

According to a recent estimate, milk production in India totalled 25 million metric tons, consisting of 16 million metric tons of buffalo milk, 8.4 million metric tons of cow milk and 0.68 million metric tons of goat milk. This indicates that the buffalo is a better milk-yielder than the cow. A wide variety of dairy products are obtained from cattle Milk produced in the country to the extent of 39 per cent is consumed as such and the rest is utilized for the production of the following milk products.

1. Milk. Whole milk—contains all the natural fat. Skimmed milk—milk after the removal of cream.
2. Milk products: Cream, cheese, curd, butter, ghee, *khoa*, ice-cream, casein.
3. Concentrated milk products. Sweetened condensed milk, milk powder (full cream and skimmed), infant milk food, malted milk food.

Other products Beef, buffalo meat, hides, skins, bones, hair.

Cattle dung is rich farm-yard manure. The gobar gas, as it is called, is a rich source of energy and has been put to various uses recently. Even after yielding the biogas the residue retains its fertilizing qualities.

Sheep and Goat

Sheep rearing and wool industry constitute an important means of livelihood for millions of sheep farmers and artisans. Mutton, wool and skins are obtained from sheep while goats provide meat, milk, hair and skins. Tables 32.4 and 32.5 give some of the important breeds of sheep and goats available in India. They differ from one another in their body shape, horn size and nose shape.

TABLE 32.4

Important breeds of sheep in India

Gurez	Lohi
Bikaneri	Mandya
Bhakarwal	Deccani
Nellore	Bandur

TABLE 32.5

Important breeds of goats in India

Jamunapari	Barbari
Surti	Bengal
Beetal	Marwari
Pashmina	Malabar

Feeding of Sheep and Goats

Sheep feed on green tender grass or weeds or other herbage. Goats feed on a variety of trees by browsing on the buds and foraging on a variety of plants. Improper management of goats leads to the destruction of vegetation. Oil-cakes and mineral mixture are also fed to keep sheep in good condition.

Diseases of Farm Animals

Rinderpest, Foot and Mouth disease, Anthrax, Black quarter, and Hemorrhagic septicaemia are some of the important diseases affecting farm animals. By following proper preventive and sanitary measures the spread of several diseases can be controlled. The incidence of Rinderpest and other contagious diseases can be considerably reduced by taking appropriate measures like vaccination. External parasites like lice on cattle can be controlled by applying dilute solution of insecticides like lindane. Calf losses which is a serious problem in the case of cattle can be prevented by taking proper care of the new-born calf. Cattle also suffer from common ailments like bruises, wounds, abscess, fractures. Timely control measures must be taken in all cases, utilizing the services of veterinary extension staff.

Breeding of Cattle

There are two methods of breeding, namely, natural and artificial The first method involves cross-breeding of indigenous cows with bulls of exotic dairy breeds like Ayreshire, Jersey, Guernsey, Short Horn, Brown Swiss and Holstein-Friesian. Artificial breeding involves the collection of the semen of a bull and inseminating the cow Semen is collected from high quality bulls of exotic or indigenous breeds. This method is economical and has the advantage that the semen collected from a single bull can be mated to as many as a few thousand cows at distant places. The Murrah breeds of buffaloes are in great demand for upgrading the local milch buffaloes. This breed has acclimatized in several parts of India.

Breeding of Sheep and Goats

In the breeding programme it is essential to select ewes and ram or goats that are most suitable for local conditions. Different breeds are known for quality of wool and mutton or meat yield. Improvement in the quality and quantity of wool of local breeds of sheep is being achieved through cross-breeding with exotic breeds of sheep like Dorset Horn, Suffolk Correidale or Merino.

EXERCISES

1. **Buffalo is a better dairy stock than cow. Justify the statement.**

2 List the common breeds of cattle and buffaloes of our country
3 What is a feed ? Give its classes and also the constitutents of each class
4 Name the common breeds of sheep and goat.
5. Breeding improves the animals in terms of yield, resistance to diseases Illustrate your answer with suitable examples

CHAPTER 33

Poultry

Poultry Farming

POULTRY farming has made rapid strides in many parts of our country and has made immense contribution to the nutrition and economy of the people. Poultry is closely related to the problem of nutrition. Poultry and poultry products are a rich source of animal protein and a right kind of fats for good health. Poultry is easy to raise and can acclimatise to a wide range of climatic conditions. Poultry birds have a short life span and are much more prolific breeders than larger livestock.

The average production of an Indian breed is about 60 eggs per annum. Several high-yielding varieties have been developed which can yield up to 240 eggs per annum. It has been estimated that the production of eggs in 1973-74 totalled 770 crores in our country. A large number of farms, some of them owning more than 1,000 birds, have sprung up around cities. Poultry farming has been providing employment to a large number of educated and enterprising people.

Feeding the Poultry Flock

Poultry usually gets free access to diet and, unlike other livestock, its feed is not rationed. The hen is quite efficient in converting the feed unacceptable to man into food products of high nutritional value. Carbohydrates, fats, protein, minerals, vitamins and water are the essential nutrients required by the poultry. Natural feeds contain all the nutrients although their concentration may vary. The feeds given to the birds consist of cereals and cereal by-products of corn, wheat, rice, or millets like jowar, ragi, and bajra. Oil-cake or meal, protein concentrates, fish meal or meat meal, minerals and greens are included in the feeds.

Poultry Housing

One of the prerequisities of sound poultry farming is to house the birds properly. Poultry should be provided with a comfortable, well-ventilated, dry, clear and properly lighted house. Birds of different ages should always be housed separately. The cage method of housing is followed in areas of moderate climatic conditions. Floor housing which is also called as loose housing or litter system is the most suitable and popular under our climatic and economic conditions. The birds are free to wander about and the floor is covered with litter. The litter could be chopped straw, paddy husk, groundnut hulls or dry leaves, whichever is cheaply

available locally. The poultry houses are made rat-proof and are provided with running water channels to ensure fresh water supply to the birds. Good drainage system is essential to keep the poultry yard clean.

Disease and Control

The lack of proper feed and different types of diseases take a heavy toll of poultry One major complaint against the poultry industry is that it is risky. An outbreak of diseases like Ranikhet, Coryza or fowl cholera can lead to the death of a large number of birds. However, these and other diseases can now be controlled by preventive measures like good management, proper nutrition, and timely vaccination of the newly born chicks. Administration of sulpha drugs and broad spectrum antibiotic treatment also help in curing several diseases. It is also necessary to avoid overcrowding of birds, poor ventilation and dampness in poultry houses as these favour the spread of diseases.

The immediate separation of the infected birds from the healthy ones and seeking veterinary aid is recommended to check the spread of the disease and its cure. Several diseases may affect the birds at various ages and may cause a drop in egg production. The following are some of the important diseases of the poultry.

Viral diseases: Fowl fox, Ranikhet (or Newcastle disease)

Bacterial diseases: Fowl cholera, Solmonellosis, Coryza

Fungal disease: Aspergillosus

Parasitic diseases.

(a) Internal parasites: Roundworms, tapeworms, threadworms.

(b) External parasites: Fowlmite, chickenmite, fleas, ticks, lice.

Breeding

There are a small number of pure breeds of fowls indigenous to India, such as *Aseel*, Busra, Ghagus, Brahma, and Cochin. *Aseel* is one of the best table birds with plenty of flavoured flesh. The *desi* birds generally have poor egg-laying capacity.

White Leghorn, Rhode Island Red, Plymouth Rock, New Hampshire, Orpington, Australorp, Sussex, Minorca are some of the exotic breeds utilized for the improvement of egg production in our country. A large number of these birds have been imported, bred and acclimatised to local conditions. Some of these varieties are excellent egg-layers, while others are good meat-producing birds.

These exotic breeds are being used for upgrading the *desi* breeds. The discovery of the effects of heterosis has changed the approach to poultry breeding. Cross-breeding is being utilized to raise the productivity of poultry. Some of the new hybrid lives can yield 230-240 eggs a year and have a low mortality rate. Some of the hybrid broilers (birds grown for meat) have a fast growth rate in a short period and have high nutritive value.

EXERCISES

1. What constitutes the feed of poultry birds ?
2. Name the common diseases of poultry and how they can be controlled.
3. What is the role of breeding in poultry farming ? Give examples.

CHAPTER 34

Fisheries

Aquaculture—Fisheries

FISH is a valuable and easily accessible source of food rich in proteins. Fish proteins occupy an important place in human nutrition in view of their high digestability and growth-promoting value. India abounds in fish, both fresh water and marine. Fishery development has received a high fillip in recent years in view of its vast potential as a popular protein-rich source of food and to meet the increasing export requirements. Development of fishing industry generates more employment opportunities. India has a rich potential to develop fisheries into a flourishing industry.

Our country is not only blessed with a lengthy coastline with vast resources of seas but also with innumerable inland water spreads. It has a coastline extending to 4667 km in length and a continental shelf of 2 59 lakh sq km area. In addition, the offshore and coastal areas of Andaman-Nicobar, Lakshadweep and Minicoy Islands, mangrove marshes are an enormous source of marine fishes. Further, the surface water consisting of 27,360 km of rivers, about 1,12,650 km of canals and irrigation channels running all over the country and several reservoirs, tanks and ponds impounding large quantities of water provide excellent locations for inland fisheries. Aquaculture involves fish production by proper utilization of fresh water, brackish water and coastal areas. Aquaculture plays an important role in increasing the production of protein-rich food, providing a base for ancillary industries and employment. Quick-growing fishes are selected for this purpose.

The total fish production in our country during 1973-74 amounted to 19.58 lakh tonnes, of which marine fish accounted for 12.10 lakh tonnes. India is at present among the six foremost sea-food-producing nations in the world. India is also emerging as one of the biggest exporters of sea-food to other countries.

Inland or Fresh Water Fisheries

Inland fishery deals with the fishery aspects of waters other than marine water. Potentially, the vast and varied inland fishery resources of India are one of the richest in the world. They pertain to two types of waters, namely, the fresh and the brackish. The former includes the country's great river systems, an extensive network of irrigation canals, reservoirs, lakes, tanks, ponds, etc. The estuaries, lagoons and mangrove swamps constitute the brackish type of water.

In culture fisheries, called pisciculture which generally obtains in small water bodies, the fish seed has to be sown, tended, nursed, reared and finally harvested when grown to table size. In the case of capture fisheries, which pertain to the rivers, estuaries, large reservoirs, as well as big lakes, man has only to reap without having to sow. Some important fresh-water culturable fishes are as follows :

1. *Catla*	2. *Labeo*
3. *Cirrhinus*	4. *Barbus*
5. *Cyprinus*	6. *Mystus*
7. *Channa*	8. *Clarius*
9. *Heteropnuestes*	10. *Tinca*

Marine Fisheries

Marine fishery deals with the fishery aspects of the sea water or ocean. Until recently sea fishing operations in India were confined to a narrow coastal region, leaving the off-shore and deep-sea regions left unexplored. A recent survey has revealed abundant resources of sardines and mackerel off the south-west coast. Fishing harbours are being developed at the major ports in the country. Considerable emphasis is being laid on the development of deep-sea fishing with the introduction of mechanized fish boats. Fishing trawlers fitted with sophisticated electronic fish-locating equipment have also been introduced recently to give a fillip to deep-sea fishing. An Integrated Fisheries Project located at Cochin is engaged in the exploration and utilization of marine resources and is the biggest of its kind in South-West Asia.

Some important marine fishes occuring in the seas around India are as follows :

1. *Hilsa*	2. Mackerels
3. Bombay duck	4. Cat fish
5. Ribbon fish	6. Red mullet
7. Flying fish	8. Sardines
9. Oil sardine	10. *Mugil*

It should also be noted that the fishery science also includes the culture of certain other animals, i.e., marine prawns, shrimps, lobsters, edible oysters and pearl oysters.

During recent years, the exports of marine products have been increasing significantly. There has been considerable spoilage in transporting the catch before marketing due to inadequate refrigerated storage and transport facilities. In recent years, facilities have been developed for cold storage and refrigerated transport of fish within the country. A sizable quantity of waste is available from the fish processing industries. From this material, fish meal is being produced for use in poultry industries.

EXERCISES

1. Define the term aquaculture.
2. What do you understand by pisciculture ?
3. List the important marine species of fish found in our country.

CHAPTER 35

Communicable Diseases

ANY DEVIATION from normal health leads to disease. Diseases may be physical, mental or social. Diseases can be broadly classified into two classes: Congenital, i.e., those present from birth and may result from metabolic disorder or defect in development; and acquired, i.e., those which develop after birth.

Acquired diseases can be further grouped into the following categories:

(i) Infectious diseases caused by virus, bacteria, protozoa, fungi and worms.

(ii) Degenerative diseases caused by the malfunctioning of the vital organs like the lung, the heart and the central nervous system.

(iii) Deficiency diseases caused by the deficiency of one or more nutrients.

(iv) Allergics caused by hypersensivity of the body to certain substances.

(v) Cancer caused by the uncontrolled growth of tissues in parts of the body.

Among these acquired diseases the infectious diseases are communicable, i.e., they rapidly spread from one person to another. That is why they are also known as *communicable diseases*. Other categories of acquired diseases are non-communicable diseases.

The major problem of community health has always been the control and prevention of communicable diseases. Plague, typhus and many such diseases have taken a heavy toll of human life in the past. It is only in the last century that we have been able to find means of fighting effectively these diseases. The success of the battle against communicable diseases has increased the life expectancy in recent years. The three important steps in this battle have been:

(a) to know the nature of these diseases, i.e., the causative organism and its life cycle—the knowledge of which has come from researches in *parasitology*.

(b) to find the mode of transmission of the diseases, i.e., how the organism attacks the human being. The science of *epidemiology* has helped us in finding out the mode of transmission and has, thus, enabled us to devise proper public health measures.

(c) to develop a defence mechanism for resisting the attack. The science of *immunology* has given us effective protection against the attack of these organisms.

Diseases have been a prime concern of man from time immemorial. Early man thought that diseases were caused by evil spirits. Cure therefore, consisted of pacifying

the evil spirits with the help of charms and magic.

Hippocrates (B.C. 460–359), the great Greek physician, put forward the theory of four humours. He observed that diseases are caused by the improper balance between four elements–phlegm, blood, yellow bile and black bile. His theory dominated the medical thought until the sixteenth century.

Foundations of Parasitology

Our understanding of the modern concept of communicable diseases was possible only after it was realized that it is the germs that cause diseases. After the invention of microscope in 1835, people learned about the nature of the minute organism that causes disease. As our knowledge of human parasite developed, it became apparent that most communicable diseases are caused by bacteria and virus. The credit of establishing the germ theory of disease goes to Louis Pasteur and Robert Koch. As our knowledge of bacteria expanded, new bacteria responsible for various diseases were discovered. Today, most of the bacterial diseases are well understood. In 1890, it was discovered that tobacco mosaic disease of the tobacco plant and foot and mouth diseases of cattle are caused by living organisms too small to be seen under microscope. This led to the foundation of study of viruses. Chicken-pox, measles, common cold, poliomyelitis are all caused by virus.

Foundations of Epidemiology

John Snow may be regarded as the father of the science of epidemology, i.e., the nature of the spread of communicable diseases. While investigating the epidemic Asiatic cholera in London, John Snow traced it to the polluted water of the Broad street well contaminated with cholera germs. Thus, even before the causative organism responsible for a particular disease was identified, its mode of spread was investigated.

Foundations of Immunology

Some knowledge of epidemiology and immunology preceded the discovery that micro-organisms cause diseases. The discovery of smallpox vaccine by Edward Jenner is the first milestone in the science of immunology. Jenner tested the common belief that a person who had cowpox is generally immune to smallpox. He developed smallpox vaccine by using the life organism. Louis Pasteur 's contribution to immunology was based on the application of the principle of germ-based disease to this experience of vaccination. He argued that if the germ of smallpox could be weakened in the body of the cow it should be possible to weaken or activate other germs by heat, cold, starvation and other means. The development of inoculation of anthrax and the treatment of rabies are some of the outstanding contributions of Louis Pasteur. Today, we have understood the immunization process and a number of dreadful diseases of the past are under control. Due to proper sanitation and public health measures, it is possible to prevent these diseases. In our country, through consistent mass immunization programmes and community health efforts, smallpox has been eradicated.

Nature, Cause and Epidemiology of Communicable Diseases

Before one understands the nature of various communicable diseases, it is essential to know a certain basic vocubulary. In connection with these diseases we often come across such terms as infection, infestation, parasitism, pathogen, resistance and susceptibility. What do these terms mean ?

Infection refers to the interaction between the host and the parasite with a competition for superiority. If the parasitic organism wins, the disease occurs in the host

Infestation refers to the presence of a large number of an organism of the same type causing a disease in the body of the host.

Parasitism is a relationship when one organism lives at the expense of the other. Infection is a type of parasitism.

Pathogen is any organism capable of producing a disease. Pathogenecity is the ability of the pathogen to gain entrance and produce symptoms of a disease. The degree of pathogenicity is called *virulence*.

Resistance is the ability of an organism to resist or ward off infection. Resistance may be natural or acquired. Acquired resistance may be due to previous exposure to a disease or may be due to vaccination.

Factors Influencing Infection

There are various factors that affect infection:

(a) *Tissue affinity:* Some pathogens have affinity for some tissues. Some organisms may, at one stage, have affinity for one type of tissue and, at the other stage, for another type of tissue. For example, the malarial parasite infects the human red blood cell at some stage and mosquito at another stage in its life history.

(b) *Hypersensitivity:* Animal tissues sometimes become abnormally sensitive to certain bacterial cells or their metabolic product. This technique is used in the skin test for evidence of tuberculosis. This factor also causes chronic diseases in some cases.

(c) *Infective dosage:* The number of organisms needed to produce a disease in the host is called *infective dose*. It varies with the host and the type of strain of micro-organism. The infective dose is dependent on the virulence of the strain. The more virulent strain needs a less infective dose, i.e., a smaller number of causative organisms to produce a disease.

(d) *Portal of entry:* In order to produce infection, the pathogen must enter in a sufficient number through a certain route called the *portal of entry*. For example, diseases like typhoid and cholera must enter through the alimentary canal. Diphtheria, tuberculosis and pneumonia pathogens must enter through the respiratory passage. Some pathogens enter the host cell through the bites of insects. This selectivity of portal of entry is due to a natural barrier, the skin.

(e) *Communicability:* A pathogen cannot cause a disease in epidemic form unless there are susceptible persons to infect. In effect, all epidemic diseases are self-limiting because the pathogen ultimately destroys the very host that sustains it. Unless it is able to find a new host to infect, the pathogen will destroy itself.

Therefore, communicability is important and is dependent on two factors, i.e., escape of the pathogen from the host and presence of a susceptible person; escape of the pathogen depends on the localization of the infection in the host. For example, the pathogen of typhoid fever escapes through fecal matter and that of tuberculosis through sputum.

Classification of Communicable Diseases

For the public health purpose, communicable diseases are generally classified according to their mode of transmission from man to man. Thus, these may be classified as those that are transmitted by contact; through air, through food and water and through insect bite.

Communicable diseases may also be classified, according to the nature of the causative organism, into bacterial, viral, protozoic, helminthic and fungal.

Diseases caused by Bacteria

The important bacterial diseases to be discussed here are cholera, diphtheria, tuberculosis, leprosy, tetanus, typhoid and plague. Some of these diseases are quite common and some occur rarely. Some

break out in epidemic form and others do not.

Cholera

During fairs and after floods and other natural calamities, epidemic cholera breaks out in our country. Cholera has been known for a very long time and has caused great sufferings. The incubation period, i.e., the period between the entry of the organism inside the body and the appearance of the symptom generally varies from a few hours to two or three days.

The symptoms include vomiting, acute diarrhoea and muscular cramps. The stool has 'rice water' appearance. The symptoms result in dehydration, loss of minerals and, in some severe cases, death may occur.

The causative organism is *Vibrio cholerae a gram-negative* bacterium. It is transmitted through contaminated food and water. The chief preventive measures are heating of food, boiling of drinking water, proper disposal of waste, and protection of the source of drinking water.

Active immunization is produced by making a vaccine by killing the causative organism. It is always advisable to take the vaccine, particularly before travelling to a region known to be infested with the disease or during the outbreak of an epidemic. However, proper sanitation is a better control measure because immunization is effective only for a short period.

Diphtheria

Diphtheria is a serious disease in which there is oozing of semi-solid material in the throat which forms into a tough membrane. A severe general reaction to the disease is the body's response to the toxin produced by the organisms causing the disease.

The disease usually develops within two to five days after exposure. Early symptoms may not be severe, such as mild fever, sore throat and a general feeling of indisposition. Later, however, symptoms may become very severe. Numerous complications arise. Among these are difficulty in breathing due to obstruction in the throat from the production of the membrane, general swelling and inflammation. If such complications arise, surgery may be necessary. If the heart is attacked by the diphtheria organisms, there may be a rapid and fatal heart blockade.

Although diphtheria occurs mostly in children, the disease can attack adults also. Treatment for this disease is very effective if started soon enough. Diphtheria antitoxin, when given within the first 12 to 24 hours of the appearance of symptoms, completely neutralizes the toxin produced and saves the patient from serious damage. If given after 24 hours, even the largest dose may not save the patient from severe illness or even death. The antitoxin is given by injection, usually in a single dose. Although pencillin and other antibiotics may be helpful, the primary treatment is given by injecting antitoxin.

When children are immunized against diphtheria, the immunity does not last for a lifetime. It is now customary to immunize against diphtheria along with tetanus and whooping cough. This multiple vaccine is intended for the simultaneous immunization of children against these three diseases. Immunization of the adult against diphtheria is often an uncomfortable experience. However, smaller doses of toxoid may be tolerated well by the adults.

Tuberculosis

Tuberculosis bacteria invade any part of the body and destroy the tissues. The lungs are the favourite site of infection. They release a toxin called *tuberculin*. The disease spreads mostly by the nose and throat discharges from a person suffering from an active stage of the disease. The symptoms of pulmonary tuberculosis are fever, cough,

sputum containing blood, pain in the chest and loss of body weight.

An actual diagnosis of tuberculosis is made on the basis of a positive tuberculin test, chest X-rays, positive sputum, gastric analysis and Guineapig inoculation. Tuberculosis is not hereditary. The modern treatment of tuberculosis revolves round six main factors: namely, rest, diet, drugs, surgery, rehabilitation and health education. Vaccination against tuberculosis with BCG vaccine gives considerable protection against the disease. The vaccine is injected into the skin. There are also other measures in operation for the control of the disease. Public health and medical experts have cautioned that BCG vaccination should be used to supplement rather than replace other measures of control. Those who are exposed to tuberculosis, that is, nurses, medical students, hospital employees and resident physicians, should be immunized against tuberculosis.

Leprosy

It is a chronic communicable disease caused by leprosy bacillus. The disease is characterized by skin lesions, involvement of peripheral nerves so that the infected area becomes benumbed. The other symptoms include ulcer, modules, scaly scabs, deformity of fingers and toes and wasting of body parts.

The disease is communicated only by prolonged contact with the diseased parts. But the disease is far dreaded than most communicable diseases because of the social stigma attached to it. Even after the patient has been cured of the disease, it is very difficult to rehabilitate him. It is necessary to educate the public about the actual nature of the disease.

Tetanus

It is an acute disease which is transmitted through direct or indirect inoculation of the wound. The incubation period is generally from three to four weeks.

The symptoms include painful contraction of muscles, usually of the neck and jaw, followed by the paralysis of thoracic muscles. Very often, death may result. Because of this symptom it is also called lock jaw.

The causative organism is *Clostridium tetani*. It produces a water-soluble toxin which circulates in the body. Infection may occur whenever a wound is contaminated with the pathogen. It is not transmitted from man to man and infection occurs only on direct contact. It is always advisable to have anti-tetanus toxiod injection in the case of an injury in a road accident or cut contaminated with soiled objects like street dust or animal faecal matter

It is now a common practice to immunize the infant against tetanus, diphtheria and whooping cough. Reimmunization is necessary after every three to five years.

Typhoid

Typhoid fever is characterized by continued fever, often with delirium, slow pulse, abdominal tenderness and a rose-coloured eruption or rash. Typhoid fever is spread by intestinal discharges. Any person carrying the typhoid fever germs in his intestinal tract can spread the disease to others even though the person himself may not be suffering from the disease. These persons are known as *healthy carriers*.

In addition, any person who suffers from the disease is likely to spread it to others. The principal means of spread are contaminated water and food.

Diagnosis of typhoid fever is made through laboratory detection of the germ which causes the disease in the intestinal discharges of the patient. In recent years attempts to cure typhoid carriers have been made by surgical removal of the gallbladder, in which the germs appear to be concentrated,

and by treatment with antibiotics such as chloromycetin.

The prevention of typhoid fever rests on proper community sanitation, protection of the water supply, protection of food from contamination by flies, and by personal cleanliness. Immunization against typhoid is advisable at any age during an epidemic of the disease, or during a natural catastrophe such as floods or hurricanes. Immunization is also advisable when there has been, exposure to a known carrier of the disease.

Plague

Plague was brought to India in 1895 by ships from Hong Kong. Details of plague transmission and control must be studied by all in India. The plague bacterium lives as a parasite on fleas which occur on rats, mice and other rodents. The blood-sucking fleas transmit the disease among the rats. Man gets the disease by the flea-bite or by accidental contact with the infected rats.

Sulpha drugs and streptomycin are used for the treatment of plague. The control measures of plague have shifted from vaccination of the individual to the rat-proofing of ships and the destruction of rats and fleas. A large majority of modern ships are now rat-proofed.

The World Health Organization (WHO) has expressed the opinion that vaccination against plague may be useful to the individual but it has not been given place in the International Quarantine Practice. Nowadays, plague inoculations are recommended only during an epidemic of the disease.

Diseases caused by Virus

A few important diseases caused by viruses are discussed here

Chicken-pox

Chicken-pox is caused by a virus and is usually transmitted directly from person to person or by contact with clothing or other articles soiled with discharges from an infected person. An infected person may transmit chicken-pox about two days before the rash appears and up to 14 days afterwards. One attack of chicken-pox ordinarily produces permanent immunity to the disease.

Skin eruptions appear first. All the eruptions do not appear at once, but in stages. The length and the severity of the disease is dependent upon the number of eruptions produced. In severe cases, almost the whole body may be covered. The preventive measures include isolating the patient. He should keep away from all public places until all crusts have fallen off. Calamine lotion may be applied on the eruptions. The patient, his bed and clothing should be kept clean.

Measles

Measles, or rubeola, is characterized by fever, inflammation of the respiratory mucous membranes, sensitivity of the eyes to light, loss of appetite, vomiting, and a rash or eruption of the skin. After a person has been exposed to measles, it normally takes ten to twelve days before the onset of the disease.

One of the preventive measures is inoculation of gamma globulin. This substance gives passive immunity which lasts for about three weeks. Infants under the age of six months will not need gamma globulin in most cases if the mothers have had measles. The baby would have acquired some passive immunity from the mother.

Poliomyelitis

Poliomyelitis is a generalized disease of the body caused by a virus. Although inflammation of the various parts of the nervous system occurs when a person suffers from this disease, the large motor cells in the spinal cord are more susceptible to damage There is paralysis of the voluntary muscles Until recently, poliomyelitis was regarded

as a disease of infancy and childhood exclusively. For this reason, it was called infantile paralysis. But it is now known that the disease may occur at any age.

Modern evidence indicates that poliomyelitis spreads primarily through intestinal discharges. It may also spread through contaminated food or drink and by flies or other insects that may contaminate food or drink.

The signs and symptoms of poliomyelitis depend upon the severity of the disease. In the mild case, the illness may last only for one to several days. In a more severe paralytic type, the illness is of longer duration and the fever is sustained for a greater number of days. The earliest sign of involvement of the central nervous system is relative inability to bend the head forward. The stiffness of the neck is an important sign. Paralysis starts following the weakness of particular muscles. Within two to three days the paralysis reaches its maximum. In the great majority, no paralysis develops in the first place. If it develops, there is still an excellent chance for recovery.

Poliomyelitis vaccine has now been proved to be both safe and effective. Nowadays, multiple vaccines are used for protection against poliomyelitis, diphtheria, tetanus and whooping cough simultaneously.

Rabies

It is a viral disease transmitted to man by the bite of rabid animals particularly dogs. The incubation period varies from ten days to several months.

The symptoms include severe headache, high fever with alternating stages of excitement and depression. Patients have difficulty in swallowing even liquid and have severe muscular spasm in the throat and chest. Patients die very painful death following paralysis and convulsions. Rabies is also known as hydrophobia.

The disease is not transmitted from man to man but only through the bite of rabid dogs. The main control measure is mandatory immunization of dogs.

The treatment of rabies was first developed by Louis Pasteur and is known as *Pasteur treatment*. It consists of a series of injections given daily for 14 days. The injection is prepared from "fixed virus." It induces the formation of antibody. Any person bitten by a stray dog should take this treatment as a preventive measure.

Diseases caused by Protozoa

Many diseases are caused by protozoa, most common amongst them are malaria and amoebiasis.

Amoebiasis

Several protozoa cause intestinal diseases and are transmitted through contaminated food and drinks. Most important of these, because of its wide occurrence, is amoebic dysentry. The incubation period is five days in severe infection to several months in chronic cases.

The symptoms include mild diarrhoea alternating with constipation. In severe cases there may be dysentry with mucus and blood in stool. Abscess may be formed in the liver and lung.

The causative organism is *Entamoeba histolytica* (Fig. 35.1). The sources of infection are cysts from the faeces of the infected persons. Contaminated raw vegetables, fruits and other foodstuff and contaminated water transmit the disease. The disease may be prevented by proper disposal of the faecal matter, protection of the source of drinking water and environmental sanitation. Control measures would be to identify the chronic cases and their treatment.

There is no immunization method against this disease.

Malaria

Malaria is one of the oldest and most

destructive diseases of mankind. Foul air of swamp and marshes was supposed to

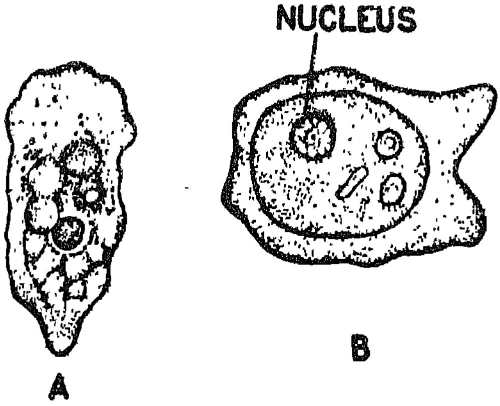

Fig. 35.1 *Entamoeba histolytica*:
A. Living stage,
B. Stained preparation

cause the disease, hence the name malaria. It is still one of the greatest health problems in the world, particularly in the tropics.

The causative organism is a unicellular organism of the genus *Plasmodium*. The incubation period of the disease varies, depending upon the species of *Plasmodium*. It is about 12 days for *P. falciparum*, 13–15 days for *P. vivax*, and 28–30 days for *P. malariae*. The disease is transmitted from man to man by the infected female *Anopheles* mosquito.

The life cycle of the malarial parasite is highly complicated. Fig. 35.2 shows the complete life cycle of the two hosts, man and mosquito. Mosquito is known as the intermediate host (insect vector). For a long time the incidence of malaria was connected with mosquito. In 1880, Lavern first observed plasmodium in the red blood cells of a patient suffering from malaria. The credit of working out the complicated life cycle of the malarial parasite goes to Sir Ronald Ross. He was awarded the Nobel Prize for this work in 1902.

Because of its complicated life cycle, the eradication of malaria is a serious health problem

The symptoms of this disease are shaking chill with rapidly rising temperature accompanied by headache and nausea. The fever subsides with profuse sweating. The cycle of fever, chill and sweating is repeated. Blood smear taken during acute chill and fever will confirm the disease. Effective drugs for complete cure are chloroquine and primaquine.

There is no immunization against malaria. Prevention and control measures involve the elimination of the insect vector, i e., mosquito. Spraying the walls with DDT, spraying thin film of oil in ditches and puddles help in checking mosquito-breeding. The use of malaria supressive drugs during an outbreak of the disease is a preventive method. The World Health Organization is collaborating with our country in our National Malaria Eradication Programme to control malaria. The incidence of malaria was reduced considerably in the last few years, but has again started rising. It is essential that people should cooperate with government and other agencies in controlling this harmful disease.

Diseases caused by Helminths

Filaria

The filarial worms are amongst the most important parasites which attack man. Filariasis is a term refering to the infection caused by the filarial worms. Repeated infection with certain species of filarial worms may result in incredible enlargement of certain parts of the body.

The legs, for example, may somewhat resemble the legs of an elephant, and for this reason, the condition has been given the name elephantiasis.

The worm responsible for the disease is *Wuchereria bancrofti*. If a mosquito, infected with these parasites, bites a man, the

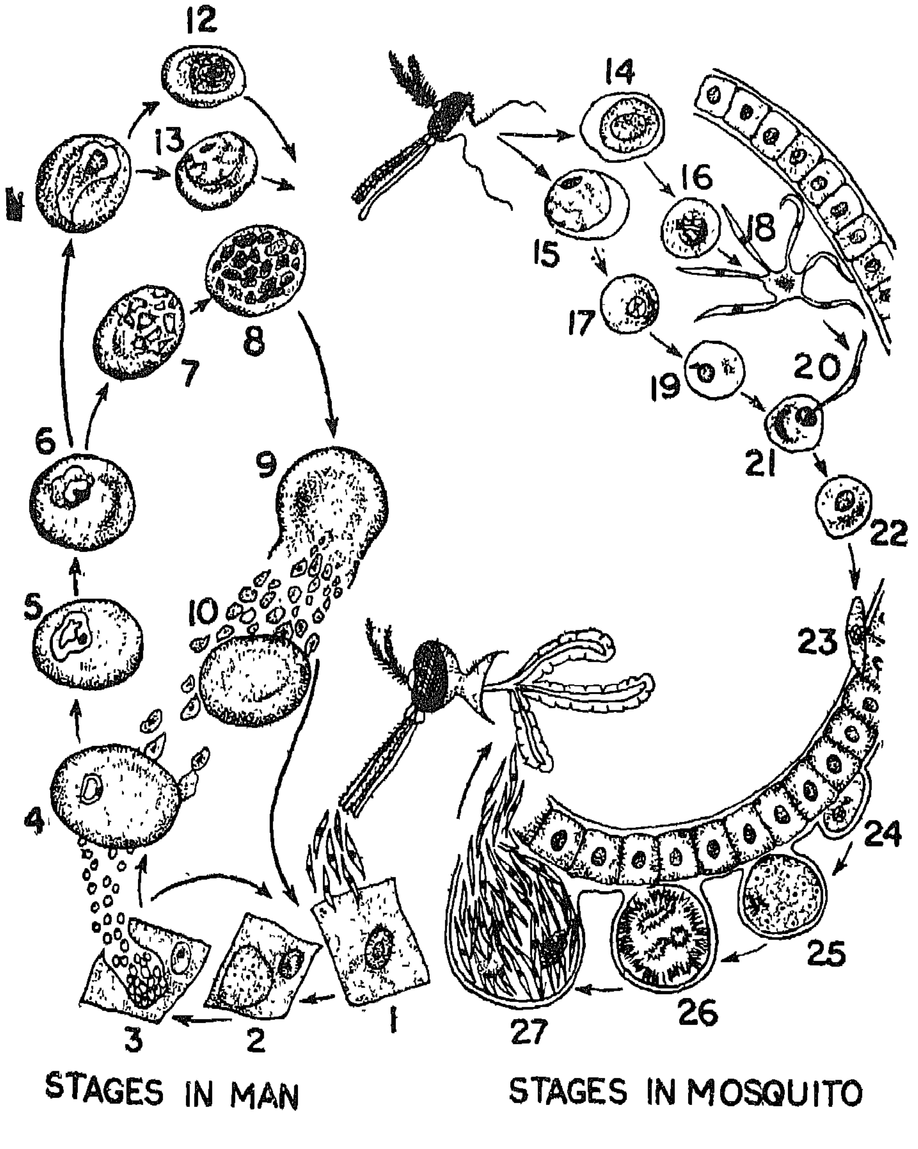

Fig. 35.2 Life cycle of the malarial parasite (*Plasmodium vivax*): 1-13 stages within man (1-3 show how the parasite grows inside the liver cell; 4-10 show a cycle within RBC-the parasite multiplies within RBC, breaks it and attacks fresh RBC; 11-13 show the growth of the malarial parasite into sexual form. Sexual forms enter within the mosquito during its blood meal.

14-27 are the stages within the mosquito: 14-19 show the development of male and female gametes; 20-22 show fusion of the male and female gametes and formation of zygote; 23 shows ookinate entering into the alimentary canal of the mosquito; 24-27 show the growth of ookinate into sporozoites (sporozoites enter into the body of man through the mosquito bite).

worms get under the skin and migrate into the lymphatic system, where they grow into adults. While living in the lymphatic system, the adult females produce a large number of tiny larvae called *microfilariae* which are carried about in the blood. If the appropriate species of mosquito takes a blood meal at this time, some of these larvae will be sucked up and will develop in about two weeks into forms infective to man. These crawl into the mouth parts of the mosquito and break out into the skin of a human host when the mosquito bites. After penetrating the skin, they migrate into the lymphnodes and grow to maturity.

The production of deformities of the body is due to frequently repeated infections. The worms cause a primary obstruction of the lymph channels causing some degree of inflammation This, in turn, causes increased amounts of protein to enter the area, which stimulate the excessive growth of the connective tissue.

A positive diagnosis can be made when adult worms are found in the lymph nodes, or by finding the microfilariae in the blood. Simple filariasis seldom requires medical treatment. Two drugs which aid in preventing the spread of the disease are Hetrazan which destroys the microfilariae in the blood, and a compound called MSE which kills the adult worms. The eradication of the host mosquito is also important.

Tapeworm

The name tapeworm is due to its long tapelike apprearance. The scientific name of the common tapeworm is *Taenia solium* (Fig. 35.3). It lives as an endoparasite in the intestine of man. One end of the tape is very narrow and carries the *head* of the worm. The head bears four cup-shaped *suckers* and a single row of curved *hooks*. The hooks and suckers are used as organs of attachment to the intestinal wall of man. The body gradually broadens posteriorly and the major part is ribbonlike and segmented. The portion immediately after the head is called *neck* which proliferates asexually to develop the posterior segments, each of which is called *proglottids*. In a full grown worm, the number of proglottid varies from 800—900.

Each proglottid includes male and female reproductive organs. Thus, *Taenia* is hermaphrodite. It practices self-fertilization, i.e., eggs are fertilized by the sperm from the same worm. The fertilized egg develops inside the female genital tract into a embryo with six hooks and becomes covered with a thick shell. This stage is called *Oncosphere* No further development takes place unless it is transferred to the body of a second host, which in the case of *Taenia solium* is pig.

A matured proglottid, stuffed with onchospheres, is detached from the body of the worm and it passes out with faeces The proglottid soon disintegrates and onchospheres become dispersed in the surroundings. When it gets a chance to enter the amnentary canal of pig, its thick wall dissolves. The embryo, called the hexacanth embryo, pierces the wall of the gut with its hook and enters into the blood stream. Finally, it reaches the muscles of the pig and becomes encysted. Within the cyst, the embryo develops. This stage is called *bladderworm*. No further development takes place, unless and until the bladderworm is transferred to the body of man. Such transfer is possible when man eats imperfectly cooked pork meat. In the gut of man, the bladderworm comes out as a small worm with the head portion. It fixes in the intestinal wall and starts to develop asexually into a full length tapeworm. *Taenia solium* has, therefore, two hosts, primary host in man and secondary host in pig.

The immediate effect of the tapeworm infection is gastric disturbances and anaemia. The extreme effects may lead to intestinal occlusion. Various anti-helminthic drugs are

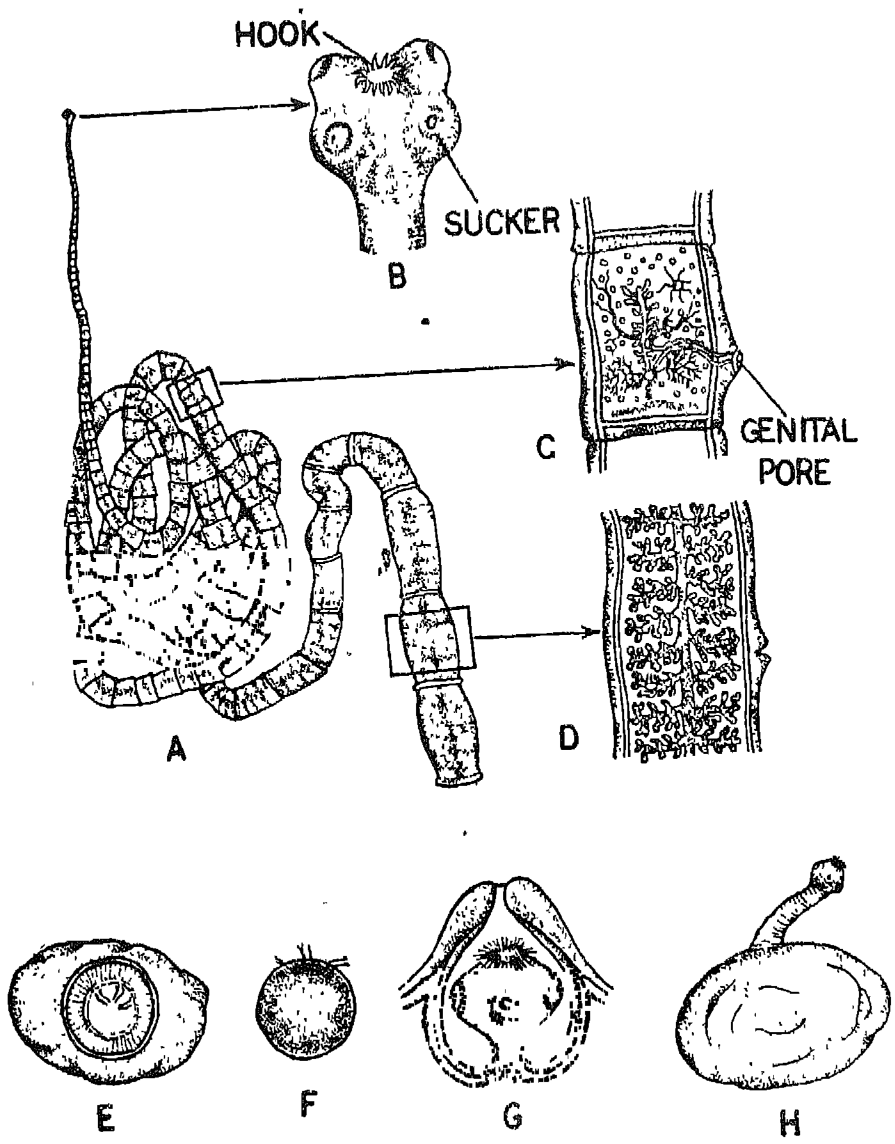

Fig 35.3 *A. Taenia solium* (External features): *B.* Enlarged view of the head region; *C.* Sexually matured proglottid; *D.* Gravid proglottid; *E* & *F.* Oncosphere stage; *G.* Bladder-worm stage; *H.* Newly emerging bladderworm.

available which in the case of infection should be used in consultation with the physician.

Round Worm

The round worm which is found in man is known as *Ascaris lumbricoides* (Fig. 35.4). It is an endoparasite, i.e., it lives inside the body of the host and it infects the small intestine. When alive, the round worm is reddish-yellow in colour but the dead worm looks milk-white. The mouth, bounded by three lips, is present at the terminal end of the anterior part. The outlet of the alimentary

canal, called anus, is ventrally placed near the posterior end. The sexes are separate.

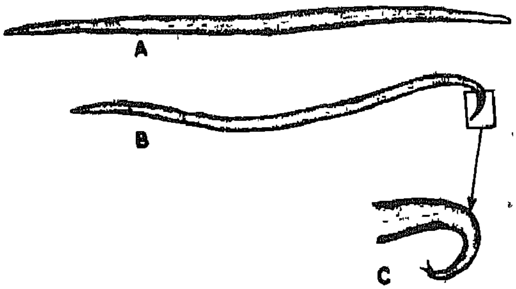

Fig. 35.4 *A*. Round worm (*Ascaris*), female
B. Round worm (*Ascaris*), male
C. Showing the posterior end of the male worm.

It is possible to identify male and female worms easily by external examination. In the males the part of the body after the anus is sharply curved downwards but in the females this end is straight. The females are larger than the males and possess a separate genital opening. There is no separate genital opening in the male, where the outlet of the alimentary canal also serves as the genital opening.

Eggs are fertilized inside the body of the female and every day nearly 20,000 eggs are liberated. These eggs come out of the body of the host with faeces, but the worms remain inside the intestine. Each fertilized egg is covered with a chitinous shell and embryo completes its development in about two weeks. These eggs enter into the body of a new host along with food and drink. The eggs hatch after reaching the intestine of the new host. From the intestine larva passes through different organs like the liver, the heart and the lungs. In the course of this journey adulthood is reached and the adults finally come to the intestine and settle there.

The infection of the round worm produces intestinal obstruction, obstruction of the Eustachian tube, appendicitis and peritonitis.

EXERCISES

1. Distinguish between communicable and non-communicable diseases.
2. What are the important steps for fighting communicable diseases ?
3. How has the science of parasitology, epidemology and immunology helped in our understanding and control of communicable diseases ?
4. What are the factors that influence infection ?
5. Enumerate the signs and symptoms of the following diseases. What community health measures have been adopted to prevent and control these diseases ?
   (a) Cholera
   (b) Malaria
   (c) Tuberculosis

CHAPTER 36

Community Health

COMMUNITY health may be defined as all such activities that contribute to the improvement of the health of a community.

Community health services involve a number of activities to maintain good health These are (i) maintaining sanitation of the environment by providing safe drinking water, proper disposal of sewage; (ii) providing facilities for prevention and control of communicable diseases such as arranging vaccination campaigns, isolating diseased cases and giving treatment; (iii) providing maternity and child health services; (iv) providing school health education, community health education, nutrition education and family welfare.

Table 36.1 gives the basic health services rendered through health centres. Health organization varies from rural to urban areas but the basic services rendered are the same.

Apart from these services, national programmes like malaria eradication, family welfare planning, etc., are undertaken with the assistance of the government and other agencies.

General Preventive Measures against Communicable Diseases

As the saying goes, prevention is better than cure. It is essential, therefore, that sufficient preventive measures are adopted to control communicable diseases. A person suffering from a communicable disease must take proper care so that it may not spread to the community It is necessary to isolate such cases and educate the other people to take precautionary measures against the disease Some of these measures are listed below :

Vaccination—Today, the facility of vaccination is available against a number of communicable diseases, such as smallpox, cholera, typhoid and tuberculosis It is the duty of every citizen to take vaccination in order to prevent the spread of communicable diseases. One should cooperate with the community health workers in their effort in this direction.

Sanitation—To fight communicable diseases, it is necessary to strike at the source. Unhygienic surroundings breed diseases. Polluted and contaminated sources of drinking water, unscientific dumping or disposal of garbage and food exposed to dust and flies are the chief sources of disease-causing organisms. Helping the sanitary workers in maintaining environmental sanitation will greatly help in the prevention and spread of a disease.

TABLE 36 1

Basic health services rendered through health centres

Medical Care	*Health Education*	*Vital Statistics*
1. Treatment and hospitalisation of sick persons 2. Referred to other hospitals	1 Personal contacts 2. Printed material 3 Audio-visual aids	Collection and cross-checking

Environmental sanitation	*Prevention and control of communicable diseases*	*Maternal and child health and family planning*	*School health services*
1. Safe water supply 2 Waste disposal through compost pits, soak pits, kitchen gardens, latrines, smokeless chullah 3 Prevention of insect-breeding places 4. Prevention of air pollution	1 Mass vaccination against smallpox, inoculation against cholera, vaccination against whooping cough, tetanus and diphtheria 2. Eradication of malaria 3. Control of leprosy, trachoma and other communicable diseases 4. Supervision of food and milk trades	1 Routine examination of pregnant mothers 2 Delivery of child, infant and post-natal care 3 Visits and immunization 4. Prophylaxis against anaemia and vitamin deficiency 5. Family planning advice and services	1 Medical check-up, treatment, follow-up 2. Immunization 3 Screening by the teacher 4 School sanitation 5 School lunch or mid-day meal 6 Health instruction

Sterilization—Most bacteria and organisms responsible for communicable diseases are susceptible to heat. Therefore, it is essential to sterilize the items of daily use of the patient suffering from such a disease Disinfectants like phenyl and dettol should be used to kill the germs Antiseptic measures should be taken to avoid infection, particularly by a person attending to a patient suffering from a communicable disease

EXERCISES

1. Define community health
2. What agencies are responsible for maintaining the health of the community ? Enumerate the various activities under the community health programme.

CHAPTER 37

Non - communicable Diseases

A NON-COMMUNICABLE disease affects only the person who is suffering from it. It is not transmitted from man to man. Thus, common public health measures of sanitation, vaccination, etc, are not applicable in controlling these diseases. But proper health education can help in preventing some of these diseases. There are some which are the result of modern life which is full of stress and strain.

Deficiency Diseases

These diseases are caused by the intake of an insufficient quantity of one or the other nutrient. Here, we shall discuss two most important deficiency diseases prevalent in our country–Kwashiorkar and Vitamin A deficiency

Kwashiorkar

This disease is caused by severe protein malnutrition. A number of children in our country suffer from this disease Such children have stunted growth, loss of appetite, anemia and protuding belly. Repeated diarrhoea, underweight and wasted muscles are the other signs The skin and hair change colour, the skin becomes blotchy, and the legs and feet become swollen.

This disease is a consequence of ill-spacing of children, prolonged breast-feeding, late introduction of supplementary food, and a disproportionately large intake of carbohydrate food.

In collaboration with the UNICEF, FAO and WHO, the Government of India has started a nation-wide programme of applied nutrition The aim of this programme is to educate people on the nutritional needs, to encourage proper food habits, to encourage food production and to operate pre-school feeding programmes.

Vitamin A Deficiency

Two important diseases caused by the deficiency of vitamin A are Xerophthalmia and night blindness.

Xerophthalmia is characterized by the failure of the tear gland in the eyes to function. In severe cases, it leads to dryness, bacterial growth and ulceration of cornea. If untreated, it may lead to blindness.

Night blindness is characterized by inability to see in dim light. Visual purple, a compound present in the retina of the eye, plays a vital role in the process of seeing. The deficiency of vitamin A affects the formation of visual purple.

The vitamin A deficiency also leads to such symptoms as dryness and scaliness of

the skin, injury to the epithelial lining of the internal organs and body cavity It plays an important role in maintaining resistance to infection.

The disease can be cured by supplementing the diet with food rich in vitamin A, such as egg-yellow, green vegetables, shark liver oil and butter, carrot, papaya and mango.

Degenerative Diseases

This category includes diseases of the heart and the central nervous system and other vital organs.

The heart is a very important organ of our body. Diseases of the heart are becoming very common these days.

Causes of Heart Diseases

One of the chief causes of heart diseases is arterosclerosis. It is basic disorder related to the coronary artery disease. The coronary arteries are weakened by the internal deposit of fatlike materials. This leads to the structural collapse and haemorrhage in course of time Sometimes, the blood flow is affected and clotting takes place, ultimately leading to an acute heart attack. It is believed that saturated fats such as those in butter and cream may be one of the most important causes of heart diseases.

Other causes of heart disorders are: rheumatic fever, high blood pressure, overweight, developmental (congenital) defects of the heart, bacterial and virus infections, severe anemia, heavy smoking, sedentary habit and overactive or underactive thyroid gland.

Symptoms of Heart Diseases

The symptoms are usually related to the failure of the heart to do its job, to the disturbances of the rhythm, or to the impairment of the circulation of the blood to the heart muscle itself. When the symptoms are associated with the failure of the coronary vessels to supply an adequate amount of oxygen and nutrients to the muscle tissues of the heart, pain may result. Sometimes, the blood vessels to the heart may rupture and cause haemorrhage in the cardiac tissues. In such cases, the pain may be exceedingly severe and must be treated by the physician immediately. The chest pain in the region of the heart may be due to many different causes. The heart pain is more likely to be of a crushing or squeezing variety. When the heart muscle itself is damaged by the lack of oxygen and nutrients, intense nausea and vomiting may also accompany the pain.

Some infants are born with hearts that have a murmur during contraction. Many young people have temporarily such murmurs during adolescence

The Heart Attack

The most serious type of heart attack is the one in which the blood vessels to the heart haemorrhage into the heart tissues or in which the blood vessels no longer carry enough blood to meet the needs of the heart muscle. This may be because of temporary constriction of the blood vessels, hardening and degenerative changes in the coronary arteries, or due to the formation of a clot. In medical terms, this damage to the heart is known as myocardial infarction.

Tobacco and Heart Disease

In the majority of patients, the heart rate increases slightly after the smoking of one or two cigarettes, and the peripheral blood vessels contract to increase the blood pressure to some extent. The effects of tobacco upon the circulatory system are due to nicotine. Opinion varies as to whether or not nicotine is a cause of heart disease.

Recent statistics suggest that there is a definite correlation between the smoking of tobacco and the increased mortality rate caused by coronary artery diseases. This does not prove, of course, that smoking by

itself is the cause of the higher death-rate from this type of heart diseases, but the correlation strongly implies that a person with heart disease might do well to give up smoking.

Heart Surgery

Since 1926, cardiac surgery has developed into a life-saving and life-extending service. Surgery has been successful in the repairing of certain kinds of congenital defects of the heart. The "blue baby" heart operations represent the surgery of this sort that prevents the mingling of the oxygenated with the non-oxygenated blood by the correction of the structural defects In recent years, successful efforts have been made to impart a new blood supply to the heart in coronary artery disease by transplantation in the heart muscle. This is called "beck operation" and has been reported as safe and effective.

The most effective means of preventing a heart disease is to live a wholesome life without becoming unduly concerned about the heart. A diet low in saturated fats may control the blood cholesterol level with subsequent reduction in the likelihood of coronary artery disease. Sound eating habits over a period of years may lengthen life and reduce the chances of heart or circulatory diseases. A person suffering from an infectious disease, high blood pressure or rheumatic fever should seek medical advice. Overweight and tendency to obesity should be checked Disturbances in basal metabolism, if detected, should be treated by the physician. Avoiding smoking, drinking and use of drugs may safeguard one against heart diseases The adaptation of work and recreation to the capacity of the heart is another means of protecting the heart and preserving health.

Stroke

The most common injury to the brain is 'stroke' In stroke, the flow of blood to a part of the brain is suddenly cut off. This, in turn, causes an injury to all the structures connected with that part

Strokes may be caused by haemorrhage from the rupture of a blood vessel, the formation of a clot within a blood vessel, spasm of an artery or the obstruction in a blood vessel by a small particle, usually a blood clot floating in the blood stream

Treatment is varied in accordance with the cause of the stroke. The patient crippled by a stroke can often be rehabilitated unless it is serious.

Diabetes

Diabetes mellitus is a disease characterized by the presence of excessive quantities of sugar in the blood and its excretion in the urine. Diabetes insipidus, on the other hand, is a disease characterized by the excessive elimination of the urine, but the urine in this case is insipid or tasteless The latter condition is due to disturbances in a part of the pituitary gland, whereas diabetes mellitus is associated with a faulty functioning of the Island of Langerhan's, an endrocrine gland in the pancreas which secretes a hormone called Insulin.

A diabetic patient drinks large quantities of water because he often feels thirsty. Other symptoms are excessive urination, increased frequency in urination, excessive appetite, loss of weight, and general weakness. The disease attacks both young and old, men and women The first obvious sign of diabetes is the presence of sugar in the urine and a high level of blood sugar.

Insulin is used not as a cure but as replacement. It is made available in well-standardized doses Certain drugs like tolbutamide can be taken orally. But these drugs cannot replace insulin

If a diabetic patient is to live a long and comfortable life, two methods of self-care are essential—administration of insulin and

analysis of the urine The health and comfort of a diabetic patient depend upon the amount of insulin taken, the diet and the amount of exercise

Arthritis

Arthritis cannot be called a degenerative disease in the strict sense One type of arthritis, called degenerative arthritis, is a disease of advancing years Arthritis is a general term applied to a great variety of diseases characterized by the abnormality of the joints. There are several types of arthritis The most common are degenerative arthritis and rheumatoid arthritis.

Degenerative arthritis commonly appear after the age of 40. In the bones, the process of aging begins early The degenerative process first attacks the cartilage. The cartilage is the shock absorber of the joints, and with its loss, arthritic changes start developing.

Rheumatoid arthritis first attacks the membrane which lines the joint (synovial membrane) causing inflammation This ultimately leads to the stiffness (ankylosis) of the joints.

Physiotherapy is a source of comfort to the arthritic patients. In general, the arthritic patient is one whose joints have grown old. With proper care, he may grow old with relative comfort.

Cancer

Cancer is a disease of the cells. Its origin is most often in the tissues which habitually renew themselves, such as the skin, the linings of the digestive tract organs of the reproductive system, the lungs, and the liver. For reasons yet unknown, the cells which normally reproduce themselves in a controlled manner suddenly proliferate in these tissues forming large growing tumours. Individual cells from these tumours may find their way into the blood stream or the lymphatic system and are carried to other parts of the body. Here they continue to reproduce and grow and interfere with the normal body process of other tissues Usually, unless treated by radiation, chemotherapy or surgery, malignant cells continue to grow until their interference with the body processes ultimately causes death.

So far as the possibility of cancer is concerned, there are seven danger signals that should prompt a person to consult a doctor These are :

1. Any wound that does not heal
2. A lump or thickening in the breast or elsewhere
3. Unusual bleeding or discharge
4. Any change in a wart or mole
5. Persistent indigestion or difficulty in swallowing
6. Persistent hoarseness or cough
7. Any change in normal bowel habits

The diagnosis of cancer is based upon one or more of the following procedures (1) biopsy, (2) X-ray, (3) microscopic examination of the body fluids, and (4) blood studies.

It is evident from medical experience that cancer can be cured in a high percentage of cases when there is an early diagnosis of this disorder. Late diagnosis greatly increases the hazard of cancer.

Cancer of the stomach is of great importance Its cause is unknown. The most effective means for discovering cancer of the stomach is the use of the X-ray or fluorescence. The use of the gastroscope, a device for inspecting the interior of the stomach, is often a valuable aid in diagnosis. Cancer of the stomach can be cured if detected soon enough.

Cancer of the Lung

During the past 25 years or so, autopsy studies throughout the world have shown an increase in the number of deaths due to cancer of the lung. There are no early symptoms of this desease that can be

distinguished from the symptoms of common respiratory diseases There are no characteristic physical signs of the disease.

The best chance for detection of cancer of the lung at an early stage rests with the periodic X-ray examination of the chest The microscopic examination of the sputum may confirm X-ray findings Surgical exploration of the chest is also done in suspected cases.

Air pollution is supposed to be one of the causes of cancer of the lung. In recent years, smoking of tobacco has also been suspected to cause cancer of the lung. It is not yet known what special ingredient of tobacco smoke is the actual cause of lung cancer. Atleast one chemical, benzpyrene, that has been proved to cause cancer has been recovered from tobacco. Other two substances suspected to cause cancer are arsenic and tar.

Leukemia

Leukemia is a malignancy (cancer) of the blood forming organs. It is a type of cancer in which the white blood cells show an abnormal increase and infiltration into other tissues, such as the bone marrow, the spleen and the lymphnodes. Acute leukemia occurs most frequently in children under the age of five and is one of the leading causes of death in this age-group. It can also occur at any age. All types of leukemia are fatal. No real cure has yet been found.

Is Cancer Hereditary ?

It has not been proved that cancer is hereditary in human beings. On the other hand, it has not been adequately proved that the disease is not hereditary. Not enough evidence is available to draw a definite conclusion.

Allergies

The term allergy is applied to any condition in which a person reacts in a hypersensitive or unusual manner to any substance or agent People may become allergic to various foods, drugs, dusts, pollen, fabrics, plants bacteria, animals, heat, sunlight, and many other things. The symptoms that result from an allergy may be of different kinds, but mostly it affects the skin and mucous membrances. Such a hypersensitive condition of the skin is caused by changes that take place throughout the body.

Two things are necessary for an allergic reaction to occur. There must first be an initial sensitization to some specific substance. This first exposure may never be noticed by the person, that is why a person having an allergy frequently finds it hard to believe that he has been previously sensitized. There must then be a second exposure to the same substance, and at this time typical symptoms of the allergy will become apparent. The allergic symptoms generally disappear rapidly following the removal of the substance to which the person is hypersensitive but they will appear again whenever there is a further exposure. Allergies may cause a wide variety of symptoms. Hay fever affects the mucous membranes of the nose, eyes and upper respiratory tracts. In asthma, the lower portions of the respiratory system are severely affected.

One of the commonest skin changes associated with an allergy is just reddening. Often, there is an accumulation of tissue fluids beneath the epidermis. Another symptom associated with an allergy is known as eczema. In eczema the skin becomes red, followed by the appearance of minute blisters. Eczema may affect any part of the body, and is one of the most severest of all allergic symptoms. Other symptoms that are occasionally observed as a result of an allergy are the appearance of nodules and large blisters.

Allergies are produced by specific foodstuffs, drugs, fabrics, dusts, pollen, plants, animals, heat, cold and light. Occasionally,

allergic symptoms appear which cannot be attributed to any of these agents. Many such symptoms are believed to be caused by mental influences upon the body. The mechanism by which these arise is not well understood.

The exact nature of the substance to which an individual is hypersensitive must be ascertained before he can be properly treated. The drugs known as antihistamines are of major importance in the treatment of many allergic disorders

EXERCISES

1. What is a deficiency disease ? What are the agencies involved in fighting deficiency diseases ?
2. What are the signs and symptoms of Kwarshiorkar ?
3. What are degenerative diseases ? Why is their prevention a concern of an individual rather than of a community health worker ?
4. What are the major causes of heart diseases ? How does the smoking of tobacco effect diseases of the heart and the lungs?
5. "Cancer is incurable and hereditary." Comment on this statement.

CHAPTER 38

Alcoholism and Drug Addiction

SMOKING, consumption of alcohol and intake of drugs are social diseases which ruin the health of the people, cause a loss in manpower and hamper economic progress. People take to these habits at the adolescent age, first either for fun or to satisfy a curiosity or on some flimsy ground. Soon, they reach a point of no return and are forced to suffer the consequences. We have already discussed about the ill-effects of smoking in the previous chapter. We shall now discuss the other two evils—alcoholism and drug addiction.

Alcoholism

The consumption of alcohol is practised in poor as well as affluent sections of society. Whatever may be the kind of drink, if it contains alcohol it causes intoxication, the effect of which is the same as of any other poison.

Intoxication begins from the first sip but early signs are not visible. With the increase in its dose the body loses its control. And, gradually, the individual loses his consciousness and in extreme cases death may occur.

People who get into the habit of drinking plead, knowingly or sheer out of their ignorance, against the harmful effects or consequences of drinking alcohol. They begin with a small dose, but soon many of them become addicted and they start consuming alcohol frequently and in large quantities. When they come to realize that they have become the victims of the hazards of alcohol, then it is too late for them to give up the habit.

Effects of Alcohol

Research studies have revealed that the people who resort to drinking offer one or more of the following reasons: (1) social pressure, (2) feeling of independence, (3) liking of the taste, (4) desire of excitement, (5) desire to escape from such realities of life as disappointments and failures, and (6) hardships and monotony of everyday life.

Whatever may be the reasons, it has been proved that the intake of alcohol affects individual health, family life and ultimately creates several community and social problems.

Effects on Health

Many people drink alcohol for some "stimulation", but in reality it depresses the nervous system, thus acting as a sedative, analgesic and anaesthetic agent. It reduces the efficiency of every tissue of the body.

In a chronic alcoholic the axons of the nerve are inflamme, thus causing neuritis. The prolonged effect of alcohol on the nervous system causes various mental and physical symptoms.

Alcohol no doubt provides more energy and produces heat in the body, but, at the same time, it dilates the blood vessels. Thus, the heat generated is quickly lost. Due to constant dilation, the arterial walls soon become brittle and rigid. Such a change in the property of blood vessels and deposition of alcoholic fat affect the working of the heart.

A small quantity with low concentration of alcohol stimulates the secretion of gastric juice. But an increased quantity with higher concentration has the opposite effects. Alcohol affects the lining of the stomach and causes inflammation. In most cases, the drinkers (specially those who drink on an empty/stomach) become the victims of gastritis.

The most important organ which is damaged by alcohol is the liver. The liver is the storehouse of glycogen but alcohol causes the storage of fat in the liver. Gradually, the liver hardens and dries up. Once the liver is damaged, it affects the other organs of the body also.

The users of alcohol neglect their health and soon the body loses its resistance to infections. The alcoholics are in most cases victims of malnutrition and are easily susceptible to diseases like pneumonia.

Effects on Family and Community

The consumption of alcchol not only creates problems to the drinker but directly or indirectly affects the family and community life.

Alcoholic drinks are costly and most drinkers, because of their selfish habit, deprive their children and other members of the family of the basic needs. Thus, they create health and other problems. The drinking of alcohol is invariably associated with social crimes and dissolution of moral and cultural inhibitions.

Violence and other corrupt practices in the community are often directly or indirectly due to the consumption of alcohol. The intake of alcohol increases the rate of industrial accidents and decreases production. Traffic accidents are often due to drunken drivers. Illegal activities like production and selling of illicit liquor increases anti-social activities.

Drug Addiction

Drugs are normally used for the treatment of diseases. These are chemicals which interact with the central nervous system and affect the individual physically as well as mentally. The prolonged use of drugs may lead to the dependence of the body on them. This is drug addiction. Some people, without any medical advice, start taking drugs and soon become drug addicts. Certain drugs form habit, but some make the body completely dependent upon them. It is possible to get rid of the habit-forming drugs, but, because of serious withdrawal effects, it is extremely difficult to give up those drugs on which the body becomes too dependent. Drugs may be classified into two groups :

(a) Narcotics which depress the activities of the central nervous system, e.g., opium and its derivatives, variety of synthetic substances.

(b) *Stimulants* which increase the activities of the central nervous system either by directly enhancing the activities of the cells or by blocking normal inhibitory activities of certain nerves, e.g., amphetamine groups.

How Drug Addiction Starts

There are several reasons causing drug addiction.

1. *Curiosity*—Frequent reference to drugs in newspapers, literature and on

radio makes a person curious to have personal experience of the taste of a particular drug.

2. *Peer group pressure*—Constant description by friends about the "good feeling" creates a temptation. Such inspiration from friends and peer groups act as a pressure to start with drugs.
3. *To overcome frustrations and depressions*—The desire to get solace or relief from personal problems initiates the use of drugs. The school children who take refuge in drugs are usually lonely, unloved and insecure.
4. *Excitement and adventure*—It is natural for the young to look for some exciting work. The intake of drug being illegal satisfies that feeling of excitement and adventure.
5. *Looking for a different world*—Some people believe that drugs open up a new world of perception. It increases the ability to appreciate the aesthetic beauties, helps in intellectual enlightenment and creativity.
6. *Desire to do more physical or mental work*—Some people use drugs to increase their working power. Many students use drugs to work whole night before examination. In most cases this leads to mental-breakdown.
7. *Persistent use to get relief from pain*—People suffering from pain often take drugs for relief. Such persistent use is sometimes based on medical prescription. This practice makes them addicts.
8. *Family history*—Examples of parents or members of the family using drugs act as the most natural stimulant.

Whatever may be the reason, most drug addicts suffer from a feeling of insecurity and are psychologically maladjusted. They have dull, unhappy and unbearable life. Throughout the world drug addiction is increasing and is particularly predominant among the youth. It is extremely difficult to identify a beginner. The user of alcohol or tobacco may give out a smell but the intake of drugs does not have such identity. Moreover, drug users at the initial stage are very docile, peace-loving and quiet. They know that they are involved in an illegal act and thus do not want to take any chance of being detected. When they are detected, then they are already addicted and it becomes extremely difficult to rehabilitate them.

Effects of Drugs

Whatever may be the reason for drug intake or whatever may be the initial results, all drugs (both narcotics and stimulants) are harmful to the body. The ill-effects of some of the drugs are mentioned below :

Opium and its Derivatives

Opium is the extract from the unripe capsules of the poppy plant. It is either taken orally or smoked. The compounds derived from opium, like morphine, heroine and codein, are also used. Certain synthetic drugs like Pethidine and Methedone also produce similar effects.

Opium derivatives immediately reduce respiratory and cardiovascular activity, constrict the pupils of the eye, reduce the visual activity and cause nausea and vomiting. An overdose leads to respiratory arrest and death. If the supply of the drug is not available, the addicts exhibit terrible "withdrawal symptoms" in the form of muscle cramps, running nose, vomiting and epilepsy.

Products of the Hemp Plant

Bhang, ganja and charas are three drugs obtained from the dried leaves and flowers of the hemp plant (*Cannabis indica*). Another drug Marijuana is derived from another kind of hemp plant (*Cannabis sativa*). Immediately after the intake of these drugs, the pupils of the eye dilate, blood sugar

level rises and frequency of urination increases. Compared to the other drugs, these drugs may appear to be less harmful, but these may lead to the heroin addiction. Some of these drugs (e.g., Marijuana) cause anxiety and may lead to psychosis.

Products of the Cocoa Plant

The derivative is known as cocaine The bad effects are lack of sleep, loss of appetite and hallucination which ultimately lead to damaged mental functions and insanity. The misuse may also produce severe headache, convulsion or death due to cardiovascular or respiratory failure.

L S D

It is the abbreviation of the German term, D—Lysergic acid Dimethylamide 15 It is derived from Argot fungus. This drug causes chronic psychosis and severe damage of the central nervous system. Moreover, it damages (chromosomes) and leads to the production of the abnormal foetus.

Amphetamines and other Stimulants

These synthetic drugs are taken for increased activity and alertness. Higher doses cause sleeplessness.

Barbiturates

These synthetic drugs are extensively used as sedatives. They decrease the central nervous system activity, reduce anxiety and induce sleep. The intake of alcohol after a usual dose of a barbiturate may cause death. Once addiction is formed it is extremely difficult to withdraw from it. The withdrawal shows symptoms of epilepsy.

It is evident that all the drugs affect the central nervous system and their prolonged use cause permanent damage The body fails to work without the drugs. Ultimately other organs also get damaged, and the drug-users become victims of various diseases.

The drug-users not only themselves suffer from the ill-effects of drug addiction, they also bring miseries to the entire family. Since they get the supply of the drugs from illegal sources, they encourage smuggling and other associated illegal activities, resulting in several other social problems.

EXERCISES

1. Why alcoholic drinks are considered as poison ?
2. What are the harmful effects of alcoholic drinks ?
3. What are the reasons leading to the consumption of drugs ?
4. What are the bad effects of drugs ?

CHAPTER 39

Industrial Microbiology

MAN has been using microbes for his own benefit since centuries. Even in this technological era, microbes are used in industry as machinery to convert readily available and cheap raw materials into useful products Such microbial processes become economically practical only when the following conditions are obtained.

1. *The organism* employed must be able to produce appreciable amounts of the compound. It should grow vigorously and rapidly.
2. *The medium*, including the substrate which is converted by microbe, should be cheap and readily available Waste products of other industries form a suitable medium for such processes.
3. *The product* must be easily recoverable in appreciable amounts.

The main uses of microbes are in the manufacture of (a) antibiotics, (b) foods and beverages and (c) organic chemicals, including vitamins, steroids and enzymes.

Antibiotics

The word *antibiotic*, which today has become a household word, refers to a metabolic product of one micro-organism which is harmful to the other micro-organisms. Antibiotics were known by their activities before they were isolated. The Chinese used mouldy soybean curd for the treatment of boils. Pasteur and Joubert found that anthrax bacilli grew well in urine, but when certain other micro-organisms were present they disappeared.

The first systematic search by Gratia and Dath (1924) led to the isolation of Actinomycetin in strains of soil fungi (Actinomycetes). This compound, however, was never used for the treatment of patients

In 1929, Alexander Fleming reported that some cultures of *Staphylococcus aureus* which were contaminated by a mould were inhibited in their growth. There were clear zones between the areas where the bacteria and the mould grew. Subsequently, the mould was identified as *Penicillium* species. But it was only during the Second World War that the potentialities of Fleming's discovery were realized, and strenuous efforts on the part of English and American research workers led to the isolation of penicillin—named after *Penicillium*. The "contaminant mould", thus, became the source of the "miracle drug".

Since then a large number of antibiotics have been discovered, many of which are in current medical use. A list of the common ones along with the names of the organisms

which produce these antibiotics and the organisms against which these are active is given in the appendix.

Even though a large number of antibiotics have been isolated, not all of them have been useful in medicine. The properties which make an antibiotic suitable for medical use are :

1. The compound should have the ability to destroy or inhibit a variety of pathogenic micro-organisms. This is what is meant by a "broad spectrum" antibiotic.
2. It should prevent the ready development of resistancet of the parasite.
3. It should not produce in the host undesirable side effects, such as sensitivity or allergic reactions, nerve damage or irritation of the kidneys and the gastro-intestinal tract.
4. It should not kill the "normal" microbial flora of the host because doing so may upset the "balance of nature", and permit certain pathogenic bacteria which are restricted by the 'normal' flora to proliferate.

Besides their use in the treatment of human diseases, certain antibiotics are used as food preservative, and for the treatment of animal feed. Some antibiotics have found use in the control of plant pathogens. Griseofulvin, which is not suitable to man, is used in the control of bean rust. Tetracycline and streptomycin are also widely used. The application may be by foliar sprays or through the root. The other uses of antibiotics are in the preservation of food, especially fresh meat and fish. Antibiotics in very low doses as supplement in animal diet leads to better development of the animals.

General Methods for the Production of Antibiotics

The micro-organism is cultivated in a sterilized medium which, in addition to sources of carbon, nitrogen, minerals and buffers, contain precursors which may increase yield. Conditions which favour growth and high yield of the antibiotic are maintained. After inoculation with a suitable starter, the medium is maintained at both optimal pH and temperature. Aeration is necessary for high yield. Foaming is controlled by antifoam agents. Certain ingredients may be added during fermentation at intervals to increase the yield, e.g., sugar, precursors, in small quantities so that it is not toxic to the micro-organism.

The antibiotics thus produced are normally excreted into the medium, and are very small in quantity as compared to the volume of the cells and the substances in the spent medium. The recovery process consists of two steps—the first involves the removal of mycelium or cells by filtration or centrifuging, and the second involves the removal of the antibiotic from the spent medium by solvent extraction, absorption or precipitation. The purified product is made pyrogen-free by filtering through bacterial filters of suitable nature. The potency of the product is bioassayed, using standards for comparison.

Food and Beverages

Micro-organisms have played an important role in the preparation of food and beverages for centuries. Their large-scale industrial use, however, is a result of modern technology. Amongst the many products are cheese, bread, food yeasts, butter milk, alcoholic beverages, vinegar, soyasauce, etc.

Cheese

Cheese was prepared in Asia and Europe long before Christ was born. Milk from ewes, goats, cows, mares and other animals has been used in making cheese. The manufacture of cheese consists of the following steps :

1. Curdling the milk by the addition of lactic acid bacteria to fresh milk along with rennet. (Rennet contains the enzyme rennin, and is obtained from the cow's stomach). The curd produced by coagulation is separated from the liquid portion or *whey*.
2. The curd is next processed to remove moisture. If cheese is used at this stage, it is known as cottage cheese.
3. Salting is the next step. This is done by rubbing the surface with salt as well as dipping it in brine. Salt serves two purposes: first, it helps further in the removal of moisture, and second, it prevents the growth of undesirable micro-organisms.
4. 'Ripening' of the curd to form cheese is carried in a special room kept at suitable temperature and humidity. The fermenting micro-organisms, which vary according to the variety of cheese being manufactured, are added along with lactic acid bacteria at the curdling stage or at the ...ning stage, and imparting to each variety of cheese its particular flavour. The micro-organism induce proteolytic activity as well as lipolytic activity. The ripening period varies from 1 to 16 months Cheese is very nutritious because it contains about 20—30% fat, 20—35% protein, and a small quantity of minerals.

Bread-making

The use of yeast in leavening bread has been reported in the early history of Jews, Greeks and Romans. The method is still in use today with very little modification. Selected strains of *Saccharomyces cerevisiae* are mixed in the dough. Fermentation leads to the production of carbon dioxide which causes the dough to rise (leavening) and brings about a desired change in the texture and flavour.

Food yeast

Yeast itself is a very nourishing material for humans, and is often taken as food supplement. It is a good source of B vitamins and is very rich in proteins (40 – 50% of total dry matter). Food yeast is a by-product of the brewing industry, and is also cultured in a medium containing molasses, cane sugar, potatoes or other fermentable carbohydrates. The waste sulfite liquor from paper and pulp manufacture which contains carbohydrates other than cellulose forms a suitable medium for the culture of yeast species.

Torulopsis utilis. Yeast is cultured in the medium till maximum cell crop is obtained, after which it is collected, washed, dried and then marketed.

Buttermilk and Yogurt

While these two products are normally made at home in our country, in the western countries they are manufactured in bulk and sold at groceries. For buttermilk, a starter culture of *Streptococcus lactis* or *S. cremoris* and *Leuconostoc citrovorum* or *L. dextranum* is used. The latter produces volatile acids and neutral products which give the buttermilk its typical flavour. Yogurt starter cultures contain *Streptococcus thermophilus* and *Lactobacillus bulgaricus*.

Alcoholic beverages

Alcoholic beverages are manufactured by yeast fermentation of sugars. Usually, various carbohydrate sources are used to give a beverage its typical flavour, e.g., beer (barley malt), wine (grape), etc. The yeast employed is normally *Saccharomyces cerevisiae*. The biochemical reaction is as follows:

$$C_6H_{12}O_6 \xrightarrow[\text{enzymes}]{\text{yeast}} 2C_2H_5OH + CO_2$$

$$\text{Glucose} \rightarrow \text{Ethyl Alcohol} + \text{Carbon dioxide}$$

Besides alcoholic beverages, in some cases ethyl alcohol is also manufactured by this

process from any fermentable carbohydrate. When starchy material is used as a source, then it must first be hydrolyzed to simple sugars. This is accomplished by barley malt, moulds or heat treatment of an acidified medium. The common raw materials are potato, molasses, waste sulfite liquor, wood sugars. The scheme for manufacture is shown in Fig. 39.1

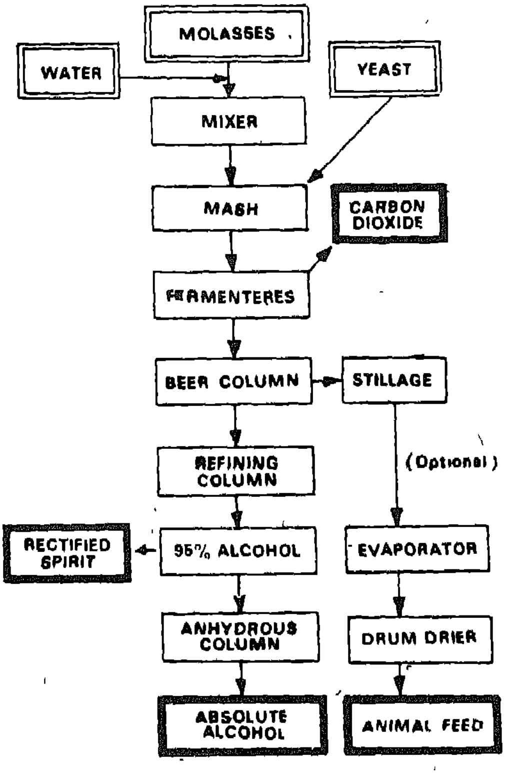

Fig. 39.1 A simplified flow chart for the manufacture of alcohol from molasses

Vinegar

Vinegar is the condiment which is made from sugary or starchy material by a two-step fermentation process. First, the sugar or starchy material is converted into alcohol by yeast fermentation and fermentation by acetic-acid. Thus, the name vinegar literally signifies 'sour wine' in French. Vinegar is named after the product from which it is obtained, e.g., cider or apple vinegar, wine or grape vinegar, malt vinegar, etc. Although vinegar has been known for thousands of years, it was not known that it was due to microbes, till Kutzing reported it in 1837. Subsequently, Pasteur in 1868 confirmed it as a physiological process.

The manufacture of vinegar involves alcoholic fermentation of the substrate by yeast (*Saccharomyces cerevisiae* varieties). After the fermentation is complete, yeast pulp and other sediments are removed by settling. The supernant is fermented by acetic bacteria. The optimum alcohol concentration is 10–13%. The reaction is as follows :

$$\underset{\text{Ethanol}}{CH_2CH_2OH} + \tfrac{1}{2}O_2 \rightarrow \underset{\text{Acetaldehyde}}{CH_2CHO} + H_2O$$

$$\underset{\text{Acetaldehyde}}{CH_2CHO} + \tfrac{1}{2}O_2 \rightarrow \underset{\text{Acetic acid}}{CH_3COOH}$$

Vinegar fermentation is allowed to proceed till maximum strength is reached. The liquid is then stored anaerobically to prevent further degradation. Aging takes place during storage, esters are formed and the harsh flavour disappears. Next, the vinegar is clarified by filtration, pasteurized and bottled.

Organic Chemicals and Enzymes

Quite a few organic chemicals are industrially produced by the use of micro-organisms. The main among them are organic acids, vitamins and vitamin precursors, dextran, steroids, and enzymes.

Organic Acids

Some of the common organic acids are produced industrially by micro-organisms. Mention has already been made of the acetic acid fermentation (see vinegar.) Other

TABLE 39.1
Organic acids produced industrially by micro-organisms and their uses

Acids	*Organism*	*Raw materials*	*Application*
1 Lactic acids	*Lactobacillus delbruck L. bulgaricus and Streptococcus lactis*	Acid hydrolyzed, corn starch or potatoes, whey, molasses, waste sulphite liquor, plus nutrients according to the organisms used	Edible grade of lactic acid is used in confectionery extracts, fruit juices, essences, lemonades, pickles curing of meat, in canned vegetable and fish products, where it acts as a preservative It is also used in the making of effervescent beverages, in dyeing of silks and other textile goods, a mordant in printing of woollen, in leather industry for deliming of hides and vegetables tanning, as flux for solder, in plastic industry. Salts of lactic acid also have wide utility
2. Acetic acid	*Acetobacter* sp.	Fruits, sugar containing syrups, hydrolyzed starchy material	Vinegar and other industrial uses of acetic acid
3. Citric acid	*Aspergillus niger*	Sugar	(i) Medicine, (ii) flavouring extracts, (iii) foods and candies, (iv) manufacture of ink, (v) dyeing (vi) engraving.
4. Gluconic acid	*A. niger, Pencillium purpurogenum* and *P. chrysogenin*		(i) Pharmaceuticals, (ii) calcium gluconate is used as a source of calcium in feeding infants and pregnant women, and for treating milk-fever in high-producing dairy cows.
5. 2-keto gluconic acid	*Pseudomonas* sp.	Glucose, gluconic acid	Intermediate for D-arabo-ascorbic acid
6. 5-keto gluconic acid	*Acetobacter suboxydans*	Glucose	Intermediate for tartaric acid

acids produced by fermentation processes and of commercial interest along with their

applications are listed in Table 39.1.

Vitamins and Vitamin Precursors

Mention has already been made of food yeast as a source of B vitamins. Besides this, *vitamin B_{12}*, a water soluble vitamin, also called *cobalamin*, is also produced by micro-organisms. Vitamin B_{12} is mainly produced by bacteria and actinomycetes, while moulds and yeasts are not. Commercially used organisms are *Streptomyces olivaceus* and *Bacillus megatherium* which are grown in media containing corn sugar, or corn syrup or cane molasses or starch as a carbon source. The vitamin is concentrated in the cells After maximal growth, the cells are harvested by centrifugation, filtration or decantation, and used as animal feed supplement with or without drying. For medical purposes, the pure vitamin is obtained by autolysing the cells in water at 100°C – when the vitamin is liberated into the aqueous phase, from where it is concentrated and purified. Vitamin B_{12} is used to supplement animal feed, for treating anemia in human beings, and for increasing appetite.

Riboflavin (vitamin B_2) is produced by a number of micro-organisms, including yeasts, yeastlike microbes (*Ashbys gossyppi, Eremothecium ashbyii*) and bacteria. Commercially used organisms are *A. gosypii, E. ashbyii, Closteridium butyricum* and *Cl. acetobutylicum*. Riboflavin is recovered from the substrate by solvent extraction with butanol, or by adsorption on Fuller's earth or silica-gel. It is a bitter, odourless, crystalline, yellow-orange powder in its pure form. Riboflavin is essential for growth and reproduction in human beings. *L-Sorbose*, the precursor of ascorbic acid, is commercially produced from D-sorbitol by biological dehydrogenation. The organisms capable of this conversion are the various species of *Acetobacter*. The flow chart for the production is given in (Fig. 39.2) The

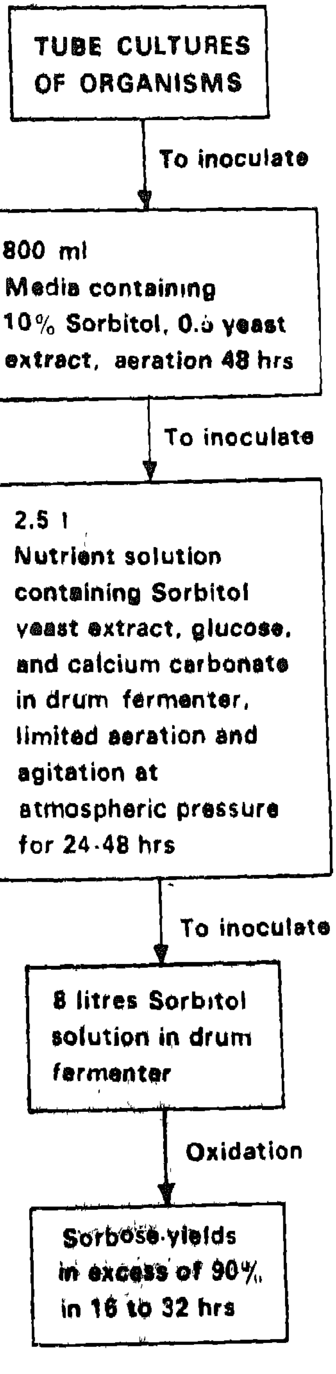

Fig. 39.2 Flow chart for the production of sorbose from sorbitol.

TABLE 39.2

Microbial enzymes and their applications

[illegible]	[illegible]		Application
[illegible]	[illegible]	α-amylase	(i) Liquefaction and saccharification of starch, (ii) Reduction of viscosity of chocolate syrups, (iii) Clarification of turbidity of fruit juice caused by starch, (iv) Desizing of textiles, (v) Sizing of paper, (vi) Sizing and desizing of textiles
		β-amylase	(i) Production of corn syrup, (ii) Modification of dough in backing industry, (iii) Correction of deficiencies in digestive enzymes
[illegible]	[illegible]		
[illegible]	[illegible]		Production of dextran; production of fructose
[illegible]	[illegible]		Removal of oxygen in presence of glucose; removal of glucose from food products (e.g., eggs before drying)
[illegible]	[illegible]		Production of soft centres in candy
[illegible]	[illegible]		Prevention of sandiness in dairy products such as ice-cream, processed cheese, etc.
[illegible]	[illegible]		Making cheese from pasteurized milk
[illegible]	[illegible]		(i) Clarification of fruit juice and enzymes, (ii) Preparation of green coffee, (iii) Acceleration of filtration of fruit products, (iv) Retting of flax for production of linen
[illegible]	[illegible]		Destruction of antibiotic action of penicillin
[illegible]	[illegible]		(i) Liquefaction and hydrolysis of casein, lactalbumen, gelatine and other proteins, (ii) Destruction of gelatin sizes, (iii) Chill-proofing of beer, (iv) Unhairing of soaked hides, (v) Removal of stains, (vi) Manufacture of liquid glue, (vii) Degumming of silks

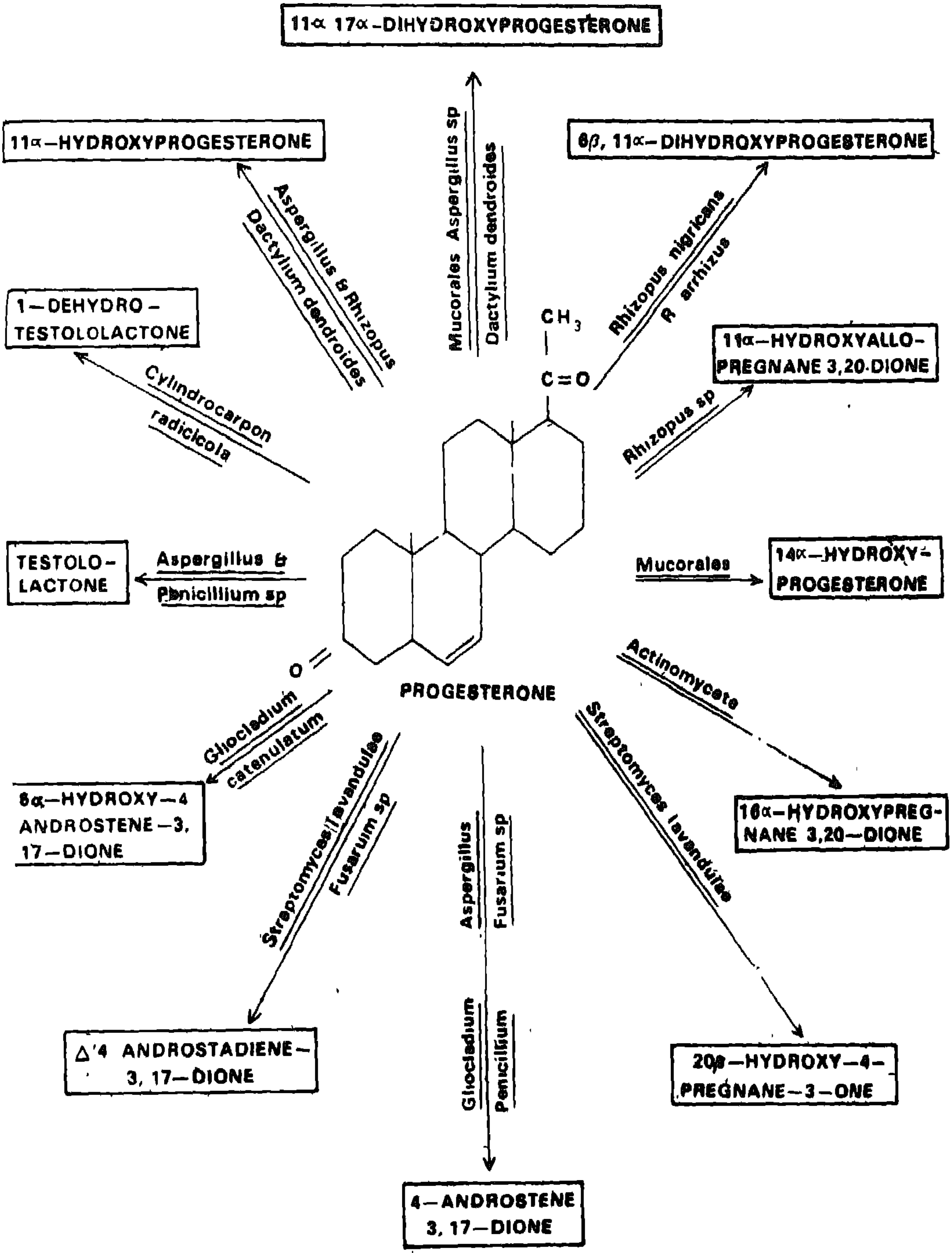

Fig. 39.3 Some steroids produced from progesterone by microbiological transformations.

l-Sorbose is then used in the manufacture of vitamin C.

Dextran

Dextrans are of particular interest in medicine as they are used as blood plasma extenders. They are polymers of D-glucose and also are polyglucosans. Dextrans may be produced by the fermentation process or by the use of the enzyme dextran-sucrase which is also obtained commercially from micro-organisms. The enzymatic process has an advantage of producing directly a reasonable amount of dextran of molecular weight suitable for clinical use. Industrially, *Leuconostoc mssenteroides* is used for the production of dextrans of suitable molecular size.

Steroids

Steroids are complex organic molecules amongst which can be listed the human hormones and cortisone. Steroids are finding wide use in family planning and in the treatment of diseases which are difficult to care These steroids are manufactured by a combination of chemical and micro-biological methods. Progesterone can be converted to various other steroids, the exact product being determined by the type of micro-organism used (Fig. 39.3).

Enzymes

Microbes are also the source of various enzymes which have wide industrial application. The most common among them are lactic and acetic acid. Lactic acid manufacture uses as its raw material waste products from other processes utilizing industrial microbiology, e.g., whey which is a waste from the manufacture of cheese. A list of commercially produced microbial enzymes and their uses is given in Table 39.2.

EXERCISES

1. Describe the general properties of antibiotics which make them suitable for medicine.
2. Name the micro-organisms associated in the manufacture of (1) Vinegar, (2) Alcohol, (3) Tetracyline, (4) Citric acid.
3. Microbes help us utilize the waste products of industry. Justify this statement.
4. Describe the uses of micro-organisms in the processing of milk products.
5. Write a short essay on "Yeast in food and beverage industry".
6. Write short notes on the manufacture and uses of (a) yogurt, (b) dextran, (c) steroids.

APPENDIX

A list of common antibiotics, organisms producing them and organisms sensitive to these antibiotics

Antibiotics	*Producing organisms*	*Sensitive organisms*
1. Penicillin	*Penicillium notatum*	Gram-positive bacteria; *Neisseria*; Spirochaeteo; actinomycetes; clostridia; *Corynebacterium diptheriae.*
2. Streptomycin	*Streptomyces griseus*	Gram-positive and gram-negative bacteria; *myco-bacterium tuberculosis*; actinomycetes.
3. Bacitracin	*Bacillus licheniformis*	Gram-positive bacteria; clostridia; *Treponema*; *Histoplasma capsulatum.*
4. *Chloromycetin*	*Streptomyces venezuelae*	Gram-positive and gram-negative bacteria; ricket-tsial and large viruses; *Endomoeba Borrelia, Actinomyces boris.*
5. Chlorote-tracycline	*Streptomyces aureofaciens*	Gram-positive; and gram-negative bacteria; ricket-tsial and large viruses.
6. Tetracyline	Catalytic hydrogenation chlortetracyline	*Klebsiella pneumoniae*; Type A *Streptococcus nitis*; *Salmonella typhose, Pasturella multocida*; some staphylococci.
7. Erythromycin	*Streptomyces erytheraeus*	Gram-positive bacteria; some gram-negative bacteria; rickettsial and large viruses.